

# REVIEW OF EDUCATIONAL RESEARCH

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## Methods of Research and Appraisal in Education

Reviews the literature for the three-year period since the issuance of Volume XV, No. 5, December 1945.

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This issue of the REVIEW was prepared by the  
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## FOREWORD

THIS issue of the REVIEW, the fifth devoted to methods of research and appraisal in education, follows the pattern of summary and review used in the third and fourth cycles published in December 1942 and 1945, respectively. Limitations on space allowed for various chapters have required selective rather than complete discussion of all research studies published during the three-year period. Contributors to this issue have charted the significant trends, and have frequently indicated their critical estimates of studies. Their generous contribution is acknowledged.

Trends of special importance in methods and technics of educational research which have become more apparent in the three-year cycle covered by this issue of the REVIEW are presented in summary form in appropriate chapters. Bibliographic and documentary research has been characterized by enlarged and improved bibliographic guides and critical evaluation by experts of the canons of historiography. In diagnostic and synthetic studies of individuals, the trend has been toward the use of projective technics, including sociodrama and the nondirective interview, for research in personality. In trend, survey, and evaluation studies increasing activity has occurred in the construction and application of informal technics to appraise the less tangible objectives of education and in follow-up studies. Research methods have shown an increasing use of appropriate logic of induction for the sampling used and more efficient experimental designs based upon analysis of variance methods. Observational methods of research have revealed improved technics in analysis of documents, rating methods, opinion surveys, and observational instruments and aids. In tests and measurements, advances were made in technical construction of tests, more adequate measurement of long-established objectives, and the distinction between measurement of detailed subjectmatter content *versus* evaluation of general educational outcomes. Recent developments in statistical theory emphasize statistical technics of factorial design rather than those applied to studies using the so-called "law of the single variable." Articles on computational technics have increased in number rapidly during the three-year period covered by this review.

One member of the committee indicated the following problems which should receive increased attention and effort from research workers in this field. Briefly, these problems are: (a) an analysis, description, and history of trend, survey, and evaluation studies in recent years; (b) a definition of appropriate methodology for evaluation; (c) an analysis of studies in education which deal with what is desirable or what should be done in educational research; and (d) a comprehensive and critical review of educational tests—perhaps an entire issue of the REVIEW devoted to this topic. These suggestions indicate some of the unfinished work that offers a challenge to research workers.

J. WAYNE WRIGHTSTONE, *Chairman*  
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## CHAPTER I

### Library Resources and Documentary Research

CARTER V. GOOD

THE description of library resources, bibliographical technics, and documentary research presented by Scates (71) in the December 1945 number of the REVIEW and by Good (37) in the December 1942 issue is carried forward in this chapter. The topics treated include: (a) library functions, organization, cooperation, and resources; (b) general treatises or manuals on library aids and technics; (c) guides to periodicals and books; (d) encyclopedias and dictionaries; (e) guides to theses and selected research projects; (f) serial and occasional bibliographies and summaries; (g) institutional and biographical directories or handbooks; and (h) historiography in history proper, education, psychology, sociology, philosophy, science, and related fields.

#### Library Functions, Organization, Cooperation, and Resources

Butler and others (17) analyzed the reference functions of the public, school, college and university, and research libraries, with special attention to problems in art and music, map collections, social sciences, science and technology, the humanities, administration, and in personnel and training. Wilson and Tauber (82) described established practice in library organization and administration, with a few critical comments on controversial issues or practices. Davidson and Kuhlman (25) outlined briefly the growing movement toward development of library and research resources in certain cooperative university centers of the South. Evans (31) described the national bibliographical services of the Library of Congress thru its facilities, collections, and experience, which have developed over a period of a century and a half.

Downs (27) emphasized the fact that international understanding is based on free interchange of the cultural records of nations as collected and preserved by libraries, educational institutions, and cultural organizations in general. International exchange of resources involves a number of possibilities and problems such as (a) exchanges between institutions; (b) exchange of government publications; (c) national bibliography; (d) reproduction of research materials; (e) coordination of book acquisitions; (f) reconstruction of foreign libraries; (g) copyright, tariff, and postal regulations; (h) translations; (i) exhibits; and (j) interchange of personnel.

Verdoorn (79) defined the chief aims of international scientific co-operation as exchange of information, attainment of objectives which scientists of a single institution or nation cannot accomplish alone, and development of an *esprit de corps* which may counteract the evils of human

international politics. He identified the means by which these aims may be approached as: (a) various forms of cooperative research, (b) international conferences and congresses, (c) activities of international commissions and committees responsible for the solution of specific problems, (d) personal contacts, visits, and correspondence, (e) exchanges of research materials, specimens, and literature, (f) exchanges of professors, research workers, and students, and (g) various publications (for example, scientific journals, abstracting journals, textbooks and reference books, popular books and journals, directories, and bibliographies and indexes).

### General Treatises or Manuals on Library Aids and Technics

Winchell (83, 84) prepared the third and fourth supplements to the sixth edition of Mudge's *Guide to Reference Books* (62), covering periodicals, newspapers, societies, essays and general literature, dissertations and research projects, encyclopedias, dictionaries, philosophy and psychology, religion, social sciences, science, useful arts, fine arts, literature, biography, geography, history, government documents, and bibliography. Barton (7) prepared a brief guide to reference books, and Bryan (16) an even smaller key to professional information, intended primarily for teachers. The third edition of Alexander's standard text and reference book on educational information and data is scheduled to appear in the near future.

### Guides to Periodicals and Books

Beginning with the educational books of 1947, an annual compilation of outstanding publications appeared in the *Phi Delta Kappan* (20), after having been published for many years in *School and Society*; this annual list of educational books identifies sixty volumes adjudged especially significant. Witmer (86) compiled a list of important books in education for 1945 and 1946, and Bay (9) characterized briefly important books in science for the past century.

The *Bibliographic Index* (35) cumulated for 1943-1946, and the fifth edition of Ulrich's *Periodicals Directory* (78) appeared. Hirshberg and Melinat (49) selected those books and pamphlets, published for the most part during the past twenty years, believed to be most generally useful in libraries, with emphasis on serials, directories, bibliographies, and handbooks which have greatest potential reference use. This compilation is a simplified, practical approach to the complexity of government documents, and provides a key to the wealth of information found in federal government publications, especially for the selective depository libraries and the smaller public and college libraries.

### Encyclopedias and Dictionaries

The forthcoming revised edition of the *Encyclopedia of Educational Research* (61) will be considerably revised and enlarged. Kaplan (52)

edited two volumes on guidance, not encyclopedic in the usual sense, but a compilation of discussions on major topics, interspersed with short articles, with emphasis on major occupations and the rise of aptitude and specific vocational tests.

Carmichael (19) edited an advanced textbook or reference work on some of the most important aspects of research on human development and child psychology. The bibliographies are extensive, with emphasis on the period since 1933. This manual is a sequel to the *Handbook of Child Psychology* (64) edited by Murchison.

Harriman (45) edited a volume of 100 signed articles, alphabetically arranged, on a miscellaneous variety of topics in the field of psychology. His title of "Encyclopedia" for this volume is misleading. Because of incomplete coverage of the subject, disproportionate treatment of subjects in comparison with their importance, and inadequate indexing, this volume will prove less satisfactory for reference purposes than the psychological handbooks and dictionaries.

Thornton (74) presented a proposal for an encyclopedia of psychological information, to embody the following features:

(a) a complete index in one volume of all psychological topics; (b) reviews of all important areas in psychology, each review written by an authority in that area; (c) complete bibliographies on all important topics in psychology, with the most significant references starred; (d) cross-references between related areas; (e) provision for correction of errors by the readers as well as the editors; (f) development of a normative dictionary of terms to simplify the task of communication of ideas thru the encyclopedia; (g) frequent revision and supplementation of reviews, bibliographies, cross-references, and index in order to incorporate the results of new researches and to eliminate errors that have been discovered.

Runes (68) edited a relatively brief volume, attempting to provide definitions thruout the range of philosophic thought. Unusual in the annals of professional writing, ten contributors disapproved the work as published, altho a number of good individual articles and definitions were included. New dictionaries of psychology (46) and of social welfare (88) appeared.

#### Guides to Theses and Selected Research Projects

The annual compilation of *Doctoral Dissertations Accepted by American Universities* (77) continued under the editorship of Trotter. The list of doctors' dissertations under way in education appeared in the *Phi Delta Kappan* (38, 39), after having been published for many years in the *Journal of Educational Research*. Other compilations of graduate dissertations covered: sociology (3, 4), history (2), political science (32), library science (22), and Negro education (55). Bowers (12) continued his annual census of research projects in sociology.

### Serial and Occasional Bibliographies and Summaries

The annual bibliography on the methodology of research appeared in the *Phi Delta Kappan* (41, 42), after publication over a period of years in the *Journal of Educational Research*. Other serial bibliographies or summaries covered were: reading (44, 76), teacher supply and demand (30), Negro education (56), and history and philosophy of science (70). Selected occasional bibliographies or summaries were published in the areas of guidance (48), mental measurements (47), character education (54), juvenile delinquency (18), and radio research (58).

### Institutional and Biographical Directories or Handbooks

Standard guides to higher institutions included the fifth edition of *American Universities and Colleges* (15) and the second edition of *American Junior Colleges* (11), as well as the *College Blue Book* (51). *A Guide to Colleges, Universities, and Professional Schools in the United States* (40) was prepared especially for returning veterans interested in higher education; it attempted a complete coverage of collegiate and professional institutions and was arranged in tabular form for ease of reference.

Bates (8) described the origin, functions, and national contributions of scientific societies, based on publications of the societies, and on other sources such as biographies and memoirs. Visher (80) analyzed the characteristics of scientists starred in *American Men of Science*, and Hughes (50) made a study of graduate schools conferring the doctorate during recent years.

### Historiography and Historical Writing

The years since World War II have been fruitful in terms of producing a variety of historical writing in education, psychology, and the social sciences. Certain of the references in this section deal with the methodology of historical research, while others are concerned primarily with the historical backgrounds of such areas as education, psychology, sociology, and philosophy.

Curti and his committee (73) arrived at a number of propositions relating to basic premises of inquiry, methodological precautions, desirable technics and principles, and relations with neighboring disciplines. Woody (87) outlined the conceptions and philosophies of history, as well as methods and technics of historical research, with illustrations and applications of special interest to workers in education.

Cone (24) emphasized that certain larger factors affect especially the disposition of written history, and also may influence rhetorical artifice. "These three major factors are purpose, content, and scope, all of which directly affect and sometimes determine the selection of facts, the organization, arrangement, shaping, proportioning, composing, and adapting the materials (disposition), and the manner of writing (style)."

Cohen (21), the logician, criticized sharply all monistic theories of historical change, but repudiated the skeptical view that, because no historical account can be complete, scientific history is impossible.

Wittels (85) maintained that the economic explanation of history leaves a gap which psychology has to fill:

An explosive part is played in historical events by unconscious defense mechanisms against bisexuality, father or mother fixation, sadism, masochism, exhibitionism, and other instincts. The content of radicalism may suddenly swing to the opposite extreme: leftists might change to radical conservatives and vice versa, because of a blind inner urge. Revolutions, the origin of religions, cannot be explained by economic (materialistic) reasoning alone. Not only the "how" of historical developments is created by exceptional men but also the "what."

Garraghan's (34) metaphysical philosophy of historical interpretation covered the meaning of history, nature and classification of sources, criticism and appraisal of sources, and synthesis and exposition in presentation of the narrative (36). Collingwood (23) traced the philosophy or idea of history from Herodotus to the present. Einstein (29) analyzed the meaning of change as it affects history, especially as illustrated in the practices of dictators; he spoke of power as the instrument of change and of history as its record.

Other recent titles of books included in this area were: *The Study and Teaching of American History* (75), *Methodology of the Social Sciences* (53), *The Use of History* (66), *Work and History* (72), *The Greater Roman Historians* (57), *Protohistory* (89), *In Defense of Materialism* (65), and *This Thing Called History* (81).

Brennan (13) wrote from the standpoint of a Thomist, seeking to achieve in psychology a reconciliation between science and metaphysics. Dennis edited a book, *Readings in the History of Psychology* (26).

Barnes and others (6) discussed social origins, ways of group life, and other aspects of sociology from Comte to Sorokin, covering the important countries of the world from the ancient Near East to the present. The second edition of *The Development of Social Thought* (10) appeared.

Rugg (67), recognizing that the present disagreement among scholars stems from the conflict of three centuries between the philosophies of authority and of experience, took his stand with Peirce, James, Dewey, Veblen, Whitman, and O. W. Holmes, and analyzed the foundations of education in psychology, sociology, esthetics, and ethics. His historical treatment covered many aspects of cultural life in this country from 1890 to the present. Broad historical treatments of the backgrounds of education were: Brubacher's *A History of the Problems of Education* (14), Edwards and Richey's *The School in the American Social Order* (28), Good's *A History of Western Education* (43), Melvin's *Education: A History* (59), and Mulhern's *A History of Education* (63).

Russell (69) sought "to exhibit philosophy as an integral part of social and political life: not as the isolated speculations of remarkable individuals

but as both an effect and a cause of the character of the various communities in which different systems flourished. This purpose demands more of an account of general history than is usually given by historians of philosophy." Other historical treatments of philosophy were by Miller (60), Fuller (33), and Gilson (36).

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## CHAPTER II

### Studies of Individuals

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IF IT is true that "wars begin in the minds of men," it is extremely important that we understand the dynamics of personality—why people behave as they do. Personality is still a vast domain in which much research is needed. During the three-year period covered by this issue, however, a number of significant books on personality have been written. Murphy's *Personality, a Biosocial Approach to Origins and Structure* (61) explores personality thru present research, not only in psychology but also in sociology, anthropology, and biology, and points the way to more significant research. Young likewise has a broad base for his study of *Personality and Problems of Adjustment* (98). Stagner has completely rewritten his *Psychology of Personality* (84), covering recent work in projective testing and supporting a point of view that emphasizes perception and the interior organization of experience. An important new anthology, *Personality in Nature, Society and Culture* (53), consisting of papers by thirty-seven authorities in the field, presents an orderly statement of our present knowledge of personality formation. The strictly experimental quantitative approach was taken by Eysenck in his *Dimensions of Personality* (32). Largely from researches carried on with 10,000 normal and neurotic subjects at a wartime mental hospital, Eysenck and his associates succeeded in factoring out and describing two main dimensions of personality, named, with reservations, "neuroticism" and "extraversion-introversion." Similar in its quantitative experimental emphasis is Cattell's *Description and Measurement of Personality* (18), in which he discussed the findings of published and unpublished studies and showed how clinical observation, rating of behavior, self-inventories, and objective tests have contributed to our understanding of the "factors, syndromes, and traits" of personality. Its emphasis is on methods of research. Entirely concerned with methodology is Rapaport, Gill, and Schafer's second volume on *Diagnostic Psychological Testing* (70).

Much of the research that would naturally be included in this chapter has been recently reviewed by Anderson and Embree in the REVIEW for April 1948 (Vol. XVIII, No. 2) and in several chapters of the REVIEW for February 1947 (Vol. XVII, No. 1) on *Psychological Tests and Their Uses*. The chapter by Havighurst, Kuhlen, and McGuire on "Personality Development" in the REVIEW for December 1947 (Vol. XVII, No. 5) likewise contains much of significance on studies of individuals.

#### Approaches to the Study of Individuals

Three important trends in approaches to the study of personality are: (a) the broadening of the developmental approach, (b) the focus on the

dynamics of personality, and (c) the approach thru the study of inter-personal relations. Developmental studies of individuals have used a combination of technics and statistical methods. More precise instruments to use in quantitative experimental developmental studies are described in the second revised edition of Gesell and Amatruda's *Developmental Diagnosis* (38).

The increased use of projective technics, personal documents, and verbatim reports of nondirective interviews in research on personality is evidence of the dynamic emphasis. Instead of focusing attention exclusively on the child's overt behavior, the observer is concerned about the springs of behavior. According to Wolff (97), he should be guided by two major concepts: (a) that a child's behavior is an expression of his "search for self," and (b) that the child's view of the world is quite different from the adult's.

Since an individual's personality is often reflected in the behavior and attitudes of other persons toward him and his response to them, the study of interaction in groups and in different environments and cultures is an important approach to the study of individuals.

### Technics for the Study of Personality

Because the description of personality is determined so largely by the instruments used, technics for research on personality are extremely important. For example, a concept of personality as a mosaic of separate traits and behavior is built by personality inventories and other instruments that collect only isolated details, whereas quite a different description of personality is obtained thru technics that reveal the inner world and motives of persons. Each of the major technics will be briefly reviewed.

### New Uses of Psychometric Tests

Psychometric tests are being increasingly used in a more flexible way. The research worker sometimes modifies the directions of standardized tests in order to study aspects of personality not revealed by test scores. For example, by adapting the administration of standardized tests to poorly adjusted individuals more valid IQ ratings may be obtained than when the directions for the test are rigidly followed (47).

Qualitative analysis of intelligence test responses has been used to differentiate between mental defectives and normal pupils. Cruickshank (20) observed the reactions of children in these two groups to the most difficult arithmetic problem in the Binet test. The mental defectives were characterized by their lack of autocriticism, unwillingness to admit inability to solve the problem, and blind manipulation of the numbers. In another experiment (88) the defective individuals were found to give superior responses on eleven items and inferior on eighteen items of the Binet test.

Other verbal tasks have been used to study disorders of conceptual think-

ing (71). Only the normal adults were able to function at an abstract verbal level, and this ability differentiated them from children and from paretic and schizophrenic patients. Other evidence that psychometric tests can be used to study emotional adjustment was obtained by Despert and Pierce (25) in their study of the relationship between test results and the total records of preschool children. Psychometric tests are being increasingly employed to differentiate between normal and abnormal persons. Rabin (69) summarized research on the use of the Wechsler-Bellevue Scale for this purpose.

An example of the diagnostic use of tests designed for another purpose was described by Klein (51). The procedure was for each cadet to estimate his performance before and after each of the six psychomotor tasks. This modified level-of-aspiration technic indicated that "cadets who overestimate their performance are more likely to fail in flying training than those who underestimate their performance." The further extension of this type of study of test results has very definite possibilities for research.

Another development in the use of psychometric tests for studying individuals is the recognition of individual differences in the suitability of tests for different subjects. Vernon (91) found verbal intelligence tests very useful for testing high-grade persons such as officer candidates, but far less satisfactory for dull and poorly educated men.

### Personality Inventories and Questionnaires

The rise and fall of personality inventories is indicated by the few references to the Bernreuter and the Bell inventories and many references to the *Minnesota Multiphasic Personality Inventory* (12, 56). Anyone planning to use personality questionnaires in a research study should read carefully Ellis' review (29) which presents evidence of the low validity of these instruments.

However, personality inventories have not been discarded for research purposes. Instead, they have been used for pattern analysis, i.e., the study of patterns of responses and personality profiles derived from them. For example, Gough (40) described a method of finding diagnostic patterns on the *Minnesota Multiphasic Personality Inventory*, and Meehl (58) has done significant work on profile analysis. The two main methods of interpreting profiles are the statistical and the intuitive, the latter being at present superior to the former. As regards the former, Du Mas (27) found the Chi-square method preferable when time is not a factor.

An attempt was made by Winthrop (96) to study personality integration by means of a paper-and-pencil test of attitude consistency. He found marked differences among college students in the consistency with which they responded to contradictory statements of attitudes. This inconsistency he attributed to "semantic blockage" and lack of a sense of logic and ability to see relationships.

The question as to whether signatures on questionnaires of a personal

nature have a substantial influence on their validity has been somewhat differently answered by various investigators. Altho the effect of signing seems slight in the majority of cases, it may be important when serious personal problems are being studied (22, 35).

Jackson (48) compared paper-and-pencil tests, interviews, and ratings with respect to their effectiveness for evaluating personality. He found that paper-and-pencil tests and interviews were influenced least by "extraneous factors" such as school achievement and intelligence. Ratings were considerably influenced by these factors, more so in the case of teachers' ratings than in the case of ratings by parents.

### Observation

As a method of studying personality, observation has become increasingly important (15). Howie (45) described how observation could be used more effectively in the classroom by selecting traits that can be observed under school conditions, knowing the subjects for at least a year, systematically focusing on one trait at a time, and making the comparison of pupils more explicit by sorting procedures. Newman (65) described a procedure for observing adolescents in informal groups, using a "composite" scale of behavior patterns and other forms of behavior-rating scales.

### Sociometric Techniques

During the last three years much has been learned about relationships of individuals in groups by means of the sociometric technic. Sociometry is the method most frequently used in research on group dynamics and the interaction within school and community groups.

The newer trend in sociometric study of individuals is to describe the personality of persons having different sociometric status, or "choice positions." Northway (66) reviewed the Toronto studies on this subject. Bonney (11) reported factors related to mutual friendships. Other investigators (54) have found that ninth-grade pupils who on the sociometric test were least accepted by their classmates, mentioned more personal problems on the Mooney *Problems Check List*.

### Personal Documents

Not many significant developments in the use of personal documents for research purposes have been reported during this three-year period. Combs (19) analyzed the autobiographies and T.A.T. protocols of forty-six university students and found much overlap in the material obtained by the two instruments.

Many valuable insights may be obtained from personal documents such as "Letters from Jenny" (50) and "Children's Autobiographies" (68).

### Expressive and Projective Techniques

The Rorschach method and other projective technics have been thoroly reviewed by Hertz, Ellis, and Symonds in the February 1947 issue of the REVIEW and by Anderson in the April 1948 issue. Accordingly, references relating to research on the technics themselves will be omitted here and this chapter limited to trends in the use of projective technics in the study of individuals.

There has been an enormous interest in projective technics to the neglect of certain other methods of studying the individual. Projective test responses may be studied in a number of different ways. Clauses, sentences, paragraphs, or episodes may be analyzed and coded as in the standard procedure for the Rorschach and the T.A.T.; or a set of categories may be applied to the responses to a card or picture as a whole (37). An insightful synthesis may be made by clinical study of the total responses.

Projective methods are being applied to everyday situations in which the person can make a relatively free, extended, and personal response. (This free response is carefully recorded. It may be elaborated by searching questions as in "the inquiry," and projective methods of interpretation are then applied.) An example of this wider application of projective methods is Sims's description of "the essay examination as a projective technic" (81) and Munroe's "use of projective methods in group testing" (60).

Projective methods are being used increasingly with adolescents and adults. An example of this trend is the application of an adapted set of the Lowenthal "Little World" material, usually used with children, to 100 adults (10). In response to the invitation to do as they pleased with the materials, the majority of the adults represented everyday life as it appeared to them. An analysis of their responses gave personality pictures of the individuals and an understanding of certain aspects of life in our culture. Correspondence with personality patterns of the same subjects obtained from biographies was high.

Projective methods of administration and interpretation are being increasingly applied to standardized psychological tests. All psychological tests are projective insofar as they reveal the individual's personality structure and inner world. Various types of personality disorders are detected by studying qualitatively as well as quantitatively, the successes and failures, the scatter pattern, and scores on subtests of an intelligence scale or other standardized test. For example, the Wechsler-Bellevue test has been used as a "nonprojective personality test" to reveal impairment of mental functions and its effect on personality (80). The use of psychological tests for this purpose is based on the assumption that mental illness manifests itself in a person's thought processes, as expressed in the test performance (70).

Among the developments in methods of studying individuals by means of the Rorschach are the graphic method proposed by Hilden (44), the inspection technic and use of diagnostic signs developed by Munroe (59)

and by Buhler, Buhler, and Lefever (14), the multiple-choice group Rorschach which has not been generally satisfactory even as a screening device, and the supplementing of Rorschach responses by free associations that further aid in the qualitative interpretation (49).

During the three-year period covered by this review, the second volume of Beck's manual for the Rorschach test (6) has been published.

More has been learned about the applicability of the Rorschach to children as young as three years (36), the personality patterns of old persons (52), the study of personality in preliterate cultures (55), and the personality factors in reading disability (93).

During the war, quick technics of measurement and statistical treatment of data were developed. *Rorschach Standardization Studies* (14) are in this direction. They aim to standardize a list of diagnostic Rorschach signs that would simplify scoring and interpretation. Some of these short-cuts can be used in civilian measurement. They should be critically examined, however, to be sure that they do not lead to superficial or erroneous descriptions of personality. Nor should these short methods be substituted for a much more significant analysis and integration of subjects' total responses.

Hertz, Ellis, and Symonds, in a chapter on the Rorschach method and other projective technics in the February 1947 REVIEW, pointed out three dangerous trends: (a) oversimplification of administration, scoring, and interpretation; (b) modification of the method to allow use by untrained persons; and (c) use of group technics before adequate study of their effectiveness.

In a comparative study of motivations as revealed in Thematic Apperception stories and autobiography, Combs (19) found considerable agreement with respect to underlying drives indicated by the two methods. The T.A.T., however, revealed more desires relative to the past and future, and also more socially undesirable desires.

The projective technics, being based on material to which the subject has no ready-made responses, are less dependent on the culture than are tests having a large element of achievement. Accordingly, they are especially valuable for studying personality in different cultures. Henry (43) described the use of the T.A.T. with about one thousand Indian children in the study of culture-personality relations.

In giving the T.A.T. to six mental patients and a close relative of each, Rosenzweig and Isham (77) obtained complementary material that supported and extended the case history data and that emphasized areas of conflict between the patients and their intimate associates.

Paintings and drawings, analyzed as to content and form (line, color, use of space, organization) have revealed personality characteristics similar to those made thru a study of the same children at home and at school (1). The drawings may be free and spontaneous or made in response to certain directions. In one experiment (95) the personality sketches made on the basis of the drawings were recognized by the students' teachers in 103 out

of 116 instances. In finger-painting, interpretation properly made gives clues as to the personality dynamics of the subjects and shows differences in age, sex, and background. The correspondence between observation and clinical diagnosis is reported to be high (62, 63).

A different use of drawing is to ask subjects to draw what they felt were the most important events of their lives. Here drawing was used as a means of communication in the same way that verbal responses to a given stimulus might be used (30).

Play technics, while used extensively for therapeutic purposes, also help to diagnose personality and show the dynamics of child behavior (3, 4). Differences between psychotic delinquent children and normally adjusted children with respect to relationships of children to father were revealed in a standardized projective doll play (5).

The Rosenzweig picture-association is a method of studying the reactions of children and adults to frustration (75, 76).

The incomplete sentence has been used for various purposes: as a screening device and as a method of measuring improvement in adjustment. It seems to reveal anxieties and hostilities better than ratings and reports (74, 78, 86, 87). It yields information on (a) conflict or unhealthy responses, (b) positive or healthy responses, and (c) neutral responses. Goodenough (39) presented the free association test as a technic of great value in giving "signs" that indicate personality structure.

### Interview

As the interview has become more nondirective, its value for studying personality has increased. Sound-recorded interviews, in which the person tries to understand himself, supply important data for research on personality (21, 73). Thus far, however, the interview has been used far more extensively for counseling and psychotherapy than for research.

### Case Study

In their evaluation of the case study as a research method Symonds and Ellis stated in the REVIEW for December 1945 that "the case study has been of increasing value to students of research in education, psychology, sociology, and anthropology; . . . progress has been made in the technics of gathering and treating case-study data for research purposes; and . . . case material has been employed in many significant investigations" (p. 352).

The case study, like the interview, has been used primarily for service rather than for research purposes. The bulk of published material consists of case histories and studies (16, 82). These case studies give a "realistic synthesis" of individuals. If more systematically collected, case studies can be used for research purposes. They have been used to study certain relationships such as that between symptoms of maladjustment and back-

ground factors (83) and differences between unselected students and students with emotional problems (57). The difficulty of interpreting a case study was highlighted by Elkin (28) who found wide disagreement on the part of thirty-nine persons who attempted to interpret the motives and adequacy of adjustment of the same case, and by Davis (23) who compared the value of the case study with data from mental tests for different purposes. He found the case study more important in clinical diagnosis and the tests in vocational guidance.

As in other technics, attempts have been made to make a quantitative analysis of case records as the basis for generalizations about clients (9). This approach is in opposition to the view of individual cases as unique.

### New Methods of Diagnosing Personality

Many new methods mostly of the projective type for diagnosing different aspects of personality have been proposed but not sufficiently validated. Among these are (a) a new perceptual test (2) in which simple letter combinations are exposed for 0.5 seconds to determine certain features of personality such as speed, accuracy, consistency, cautiousness or venturesomeness, level of aspiration, and emotional disturbances of various types; (b) a picture interpretation personality test, similar in theory to the T.A.T. but dealing with different subjects such as the child in his various relationships (13); a verbal projective technic in which the subject responds to the question: "tell me three things that are impossible" (26); (d) a modification of the Sargent test, which consists of briefly described situations emphasizing the major conflict areas of the personality and followed by questions such as: What did he (she) do? Why? How did he (she) feel? (34); (e) the study of dreams as projective documents (42).

Individuals may be studied thru their responses to annoyances. Bennett (7) found differences between neurotics and those having no record of neurotic behavior with respect to their specific sensitivity to noise and their general sensitivity to stimuli reminding them of their personal inadequacy. The phenomenon of "autokinetic movement" has been shown to differentiate between various kinds of mental patients (94). Different individuals perceive, with high reliability, various patterns of movement when they look at a stationary pinpoint of light in an otherwise totally dark room.

### New Combinations of Methods

Research using a combination of methods or a battery of tests is increasing. Many significant new developments are reported by the U. S. Office of Strategic Services in the significant report, *Assessment of Men* (90). New combinations of methods are being tried, as, for example, a T.A.T. type of test with the sociodrama (33) in which the feelings described in the picture story are acted out in the role-playing situation,

thus fusing diagnosis with therapy. Some of these methods have been combined to study the relationships among physical, mental, and motor characteristics, as, for example, the use of the sentence-completion test with psychogalvanic response (17).

In a camp situation a combination of observation, paper-and-pencil tests, and projective technics gave insight into the personality of individuals (31). The counselor's observation and his judgment recorded on the Canter questionnaire showed how the campers behaved in the group; the *Rogers Test of Personal Adjustment* gave information about their wishes and likes; the Rorschach and analyses of paintings gave insight into their personality structure.

### Diagnostic Study of School Subjects

Diagnostic methods in school subjects have been summarized in the December 1945, April 1946, and February 1947 issues of the REVIEW; in yearbooks of the National Society for the Study of Education (64), and in Russell's short review on reading disabilities and mental health (79). The most extensive research in the field of reading is Robinson's report of her clinical study of thirty children (72). The analytical approach was represented by the description and classification of the major factors, and the synthetic approach by the reports of cases in which all the data obtained by a group of specialists were brought together. By discussing the diagnostic data on each child in a case conference, the most probable causes of the reading problems became clearer and a program of treatment was suggested. The major causes of failure in this study were found to be poor family interrelationships; visual anomalies; emotional problems; inadequate methods of teaching of reading in school; neurological, endocrine, auditory-acuity, and other physical difficulties; and speech and functional auditory factors.

In Gray's "Summary of Reading Investigations" (41) few new methods of studying reading difficulties and development were reported.

An indirect method of ascertaining reading maturity was described by Husband (46). He found that a preference for the precise, concentrated passages as against the loose, ambiguous selections in both poetry and prose was associated with high intelligence. From a battery of tests certain patterns of relationships seem to be characteristic of retarded readers, as, for example, with respect to associative learning and memory-span test findings (85).

The use of instructional tests is an important means of evaluating growth in critical thinking, ability to get the author's pattern of thought, and other broader phases of the language arts not usually included in standardized tests (67).

Very little has been done in self-diagnosis and the client-centered approach in dealing with difficulties in school subjects. The cases reported have had the service rather than research emphasis.

An important practical trend is the application of diagnostic methods to everyday school tasks, i.e., diagnosis while teaching and learning. Closely allied to this trend to make diagnosis an intrinsic part of instruction, is the use of informal instructional tests to collect valuable information about how children learn specific kinds of subjectmatter.

### New Developments and Trends

Two main trends are discernible in the use of these techniques for research purposes. One is the trend toward making the collection, interpretation, and treatment of the data more analytical and objective, more like the quantitative scores on standardized psychological tests. This tendency is shown by measurement of individuals' characteristics by means of more numerous and specific objective tests (24). The same trend is shown in the attempts to objectify, analyze, categorize, and quantify case data. It is also shown in the efforts to devise definite scoring methods for the Rorschach, T.A.T., and other projective technics.

A parallel trend is the insightful synthesis of comprehensive data—responses in projective technics, case study, and various types of tests and inventories. For example, the Office of Strategic Services (90) reported the successful use of observation of persons in a variety of situations unfamiliar to them. On the basis of three days' observation of each person, trained observers obtained an understanding of the dynamics of personality that stood the test of success on the job (90).

During the war, tests were used lavishly in appraising individuals' qualifications for certain jobs. This war need has paved the way for the study of personality by means of batteries of highly-specialized tests. Research in this direction is represented by the *Thurstone Tests of Primary Mental Abilities* (89) and the *Differential Aptitude Tests* by Bennett, Seashore, and Wesman (8).

Statistical methods of treating personal data obtained on Navy and Army personnel during the war have significant implications for present research, especially in the field of vocational selection (92).

Research might be facilitated by quicker methods of administering and scoring. Along this line are the attempts to adapt the Rorschach, the T.A.T., the Minnesota multiphasic inventory, and other instruments to group methods of administration and multiple-choice or other objective-type responses, and to quick methods of scoring. These efforts, however, have not yet been successful, and may be in the wrong direction, away from clinical interpretation of whole responses.

Perhaps the most important future development lies in the use of technics such as the projective technics, the sociodrama, and the nondirective interview—which have previously been used primarily for service purposes—for research in personality.

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## CHAPTER III

### Evaluation, Trend, and Survey Studies

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THIS chapter presents brief reviews of selected evaluation, trend, and survey studies for the period July 1945 to June 1948. Most of the studies represent applications in the more usual educational situations without the benefit of financial support from private foundations or agencies. The emphasis in the various appraisal technics reveals a growing interest in personal and social characteristics as well as the more intellectual factors. Some slight increase in follow-up types of studies is apparent.

#### Formulation and Definition of Objectives for Evaluation

An outstanding contribution to the field of evaluation, *The Measurement of Understanding* (67) contains lists of objectives stated in terms of behavior and specific illustrative evaluation technics for the fields of social studies, science, mathematics, language arts, fine arts, health, and physical education, home economics, agriculture, technical education, and industrial arts. Harris (44) discussed various problems in school appraisal, and Wrightstone (99) stressed evaluating primary school achievement in terms of multiple objectives thru the use of standardized and teacher-made tests and technics in areas like readiness, attitudes, interests, creative expression, and personal-social adaptability.

At the close of World War II, the Extension Services of the Land Grant Colleges and Universities, the United States Department of Agriculture cooperating, completed thirty-one years of existence as an educational agency to rural families. A committee (94) was appointed to review its work and define the scope of the Extension Service educational responsibilities as they can be foreseen for the coming years. Likewise a 4-H Club committee (93) reviewed the objectives of 4-H Club work for boys and girls, and reformulated these objectives as ten guideposts for 4-H Club work.

At the college level, studies of objectives and their evaluation were conducted. Dunkel (25) formulated a list of twenty main goals from papers written by students and teachers. Patterns of goals for individuals were obtained by having each student rank all goals by the method of paired comparisons. Marsh (62) asked a group of college students who had just completed their first course in psychology to indicate how important fifteen stated objectives were for them and how well they thought these objectives had been attained in the course. Only a fair degree of relationship existed between how important an objective was judged to be and how well it was attained in the course.

### Construction and Refinement of Evaluation Techniques

Greene, Findley, Couey, and Stanton (40) reported training the instructors at Air University, Maxwell Field, Alabama, in construction of evaluation instruments. The instructional staff cooperated with test specialists in planning, constructing, editing, analyzing, and interpreting the findings from tests, rating scales, and other evaluative instruments. Dexter (22) constructed a questionnaire for students' evaluation of a course of study. Sartain (80) devised a scale to measure student attitude toward the difficulty of a college course and applied the scale to various psychology courses to show differences between value, interest, and difficulty of these courses.

In studying the relative effectiveness of paper-and-pencil tests, interviews, and ratings for personality evaluation, using the *California Test of Personality* and the *Woody Student Inquiry Blank* as criteria, Jackson (52) concluded that each of the technics has differential values for predicting personality traits. Raths (72) discussed social accomplishment and the process of test construction as factors making for the validity of the *Social Acceptance Test*. Raths and Metcalf (73) reported a reliability of over .90 for *The Wishing Well*, an instrument for identifying needs of elementary school children. In a comparison of a written test on superstitions, with the (unobserved) behavior of a sample of fifty-one ninth-grade pupils, Zapf (100) obtained a correlation of  $.79 \pm .03$ . A five-point scale check list of 200 items based on the ten imperative needs of youth as gathered by a committee of the National Association of Secondary-School Principals was presented for further refinement by French and Ransom (34).

### Evaluation Studies

*Elementary and Secondary School Levels.* An increasing interest in sociometric studies is reflected in the literature. Blanchard (5) summarized eighteen studies made between 1902 and 1946. He concluded that the studies were mainly at the elementary level; the technic most frequently employed was the questionnaire; and the factors which influenced choice of friends were work groups, play groups, social groups, chronological age, mental age and IQ, home background, personality traits, development, and social adaptability. Austin and Thompson (3) studied children's friendship patterns and found that personality characteristics, geographical propinquity, and similarity of interests accounted for status of and changes in friendships. An analysis of social relationships in a war-boom community by Morgan (65) thru the use of questionnaire and a sociometric test revealed the importance of father's income and level of school achievement. Cook's experimental sociographic study (13) showed how the teacher, familiar with classroom friendship structures, can modify and change such structures in the direction of increased group interaction. Horns and Watson (50) showed that for fourth- to sixth-grade children in an upper-class

private school, gentile children were more clannish than Jewish children. An interracial study of social acceptance by Raths and Schwechart (74) showed a generally higher acceptance of boys and girls along color lines (white and Negro), altho many white boys and girls showed a high acceptance of colored members of their own sex.

Gates (36) used a teacher rating scale, employer ratings, disciplinary records, participation in civic enterprises, participation in school, community and church activities, teacher observation, and peer ratings in an evaluation of civic competence of 489 high-school seniors.

Olson (69) reported an intensive study of a third grade in the University of Michigan laboratory school. Pupils were studied in an attempt to improve the quality of social relations in the group. Teachers, a pediatrician, a psychometrician, and a biologist collaborated to analyze the psychobiological characteristics of the group. Family and community relations were studied. Sociometric tests were made at the beginning of the study and again after six months of recommended treatment of the group involving changes in teacher technics and suggestions resulting from parent conferences. The follow-up study six months later gave the teachers' subjective estimate of improved social relations, but the sociometric tests failed to reveal significant changes. The conclusion was that children's social relations in a classroom have deep roots in community and family living as well as in the physical, mental, and emotional differences among the children.

Gilbert and Wrightstone reported (37) on the first systematic evaluation of camping as part of a public elementary-school program. Using matched groups of fifth- and seventh-grade pupils and a battery of tests, the investigators concluded that camping was a valuable aid in promoting democratic education. The authors recommended increased teacher education along recreational lines and an extension of camping experiences and their evaluation.

Rothney and Hansen (77) evaluated a broadcast series on the Wisconsin School of the Air. They found, primarily by questionnaire, that pupils liked the series, identified the program with their own local towns, and showed no evidence of bias on choosing favorite characters in the program. In a sub-study of the intercultural attitudes of a control (nonprogram listeners) and experimental group (program listeners), some statistically significant differences in favor of the experimental group, not necessarily attributed to the influence of the radio series, were found.

*College Level.* Various studies have compared achievement of veterans and nonveterans in college. Epler (27), Clark (9), Thompson and Flesher (86), Tibbitts and Hunter (87), Stewart and Davis (84) found generally that veterans make as good or better grades than nonveterans. Clark (9) interpreted the data as indicating that veterans were better motivated and worked harder to succeed in their classes than nonveterans. Flesher (29) made an intensive study of seventy-six women who obtained their undergraduate degrees in three years or less. Each accelerate was paired with

another student of the same age and ability at entrance. The accelerates had a superior average grade but were not superior in extracurriculum activities. Assum and Levy (2) compared the academic ability and achievement of two equated groups of seventy-one students, one group of which had applied at the Counseling Center of the University of Chicago for help on personal problems. On the college comprehensive examination, the less well-adjusted group gave evidence of poor academic achievement but had equal achievement on the college reading and writing ability tests. Toven (89) compared a counseling program at the college level for a group of 188 students who were systematically counseled for four years and a control group of 188 students who were not counseled. The study indicated that the counseled students had fewer scholastic difficulties, completed more point credits, and better realized their aims in attending college. Hewitt (46) reported guidance thru self-appraisal in a program in which use was made of (a) technical information and personality inventory tests taken by the students; (b) reports from teachers; (c) student autobiography; and (d) the counselor's summary. Griffiths (41) studied the relationship between scholastic achievement and personality adjustment of men college students. He concluded that men with brilliant scholastic records are not better emotionally adjusted than those with lower academic achievement and that unsatisfactory personality scores are not significantly correlated with unsatisfactory grades. Kilby (56) reported that students who received remedial reading instruction in college earned significantly higher final grade averages than did those in an untrained control group. Bloom (6) studied the implications of problem-solving difficulties for instruction and remediation in the College of the University of Chicago. Poorer students showed greater difficulty in understanding the nature of problems, probably as a result of reading disabilities. They exhibited attitudes of a lack of confidence and were unable often to relate a problem to information already possessed. Attempts to change problem-solving methods on an experimental basis have been successful and have resulted in improved examination marks. Wells (97) reported the psychometric work of the Grant Study with well-adjusted Harvard undergraduates. The data from psychological tests were integrated with data from general medicine, physiology, anthropometry, and psychiatry to evaluate adjustment to higher education. Reed (75) compared two colleges, K and M, on the *Michigan Vocabulary Profile Test*. Only 8 percent of the K students equaled or exceeded the median for M students. The study showed M students who had a higher average intelligence test score had read more books and more and better magazines.

*Extension Education.* In extension education, which is informal out-of-school education, evaluation studies have been conducted to obtain research findings on organizing rural adults and young people for informal teaching; their needs, interests, and social situations; planning educational programs; effectiveness of methods of teaching; the use of volunteer leadership; and measurements of results in terms of the objectives of

teaching. The conduct of these studies is based on the proposition that objective data can be obtained on which to formulate administrative policy and modify teaching procedures.

Studies of the use of radio as a teaching method have received considerable attention in recent years. Crile (15) studied the extension radio program in Ward County, North Dakota. She found that farm families were reached over the radio who were not otherwise participating in extension programs. Listeners acted upon the information they received about farm and home practices. In Wisconsin three combinations of extension teaching methods were evaluated, radio and leaflet; radio, local leader and leaflet; and local leader and leaflet (20). Radio instruction was used effectively in Massachusetts to reinforce the teaching of homemakers by local leaders on making coats, suits, dresses, and other garments (71). In New York State also, the effectiveness of the radio in teaching a technical subject (dress making) thru a long series of lessons was tested (83). The listeners adopted many new sewing practices. In Minnesota, farm people prefer the interview type of radio program in extension education, according to Hanson's (43) study of listening habits. Most farm families have radios. The extension radio programs reach farm families not otherwise participating in extension activities. The findings of studies of farm and home radio programs were summarized by Crile (21) for administrative and program-planning use. A number of other studies of extension teaching by radio are now in progress.

The use of printed materials as a method is widely used in extension teaching and has been receiving attention in extension studies. Thru personal interviews with 216 farm families, Arbour and Mason (1) found that a monthly guide of things to do on the farm and in the home in Louisiana was used by those who received it. The need for simplifying the readability of Extension Service publications resulted from the study. Clark and Mason (10) found that a monthly leaflet on homemaking and extension news distributed to rural homemakers in Connecticut was widely read with more than half using the information in the leaflet. In a study of bulletin readership in New York, Ward (95) found the bulletins widely used, read, and accepted but found that more emphasis needed to be placed on pictures, simpler presentation, and shorter publications.

Burleson (7) in Louisiana analyzed 351 of the mimeographed letters and announcements which county extension agents send to farmers and homemakers on timely farm and home practices. He found the language too difficult and concluded that the agents rate higher in their knowledge of subjectmatter than in their skill to impart it thru letters. County extension agents in Kansas furnish local editors with nearly half of the farm news appearing in local papers. Hilgendorf (47) found that the local editors preferred separate news stories rather than farm columns. They felt the people would read and get more out of farm news stories if they were adapted to the local situation.

Cowing (14) has found thru the analysis of hundreds of written mate-

rials for farmers and homemakers that the reading difficulty level of the materials was too high for good comprehension. They are being simplified by using easier words, shorter sentences, and more personal references.

The degree of organization for home demonstration teaching with rural homemakers varies considerably over the country and even within states. In Massachusetts, Billings and Collings (4) found that communities having an advisory council member and a community committee had more successful programs than communities having a less complete organization. In the former, local leaders tended to continue longer in service, were better acquainted with their functions, had a clearer understanding of the scope of the Extension Service program, participated more in program planning and were more confident in their ability to make decisions on home problems.

Some Extension Service studies were devoted to evaluating the results of extension teaching in a county or over a state. Frutchey and Wing (35), thru a geographical sampling of over 200 farms, interviewed farmers and homemakers in Windham County, Connecticut. They found that more farmers with large enterprises adopted recommended practices than farmers whose farming activities were part-time or a sideline. They concluded that when the economic stake is high the adoption of recommended farming practices is higher.

In Vermont an independent agency was asked to evaluate the work of the Extension Service thru personal interviews with a carefully selected sample of farm families. The results are given in two publications (90) (91). The study covered sources that farmers and homemakers use in getting information, farm and home practice changes, and attitudes toward extension teaching.

A cross-section sample of 212 farm families was interviewed in Pontotoc County, Mississippi (64). It was found that the use of more than one teaching method increased the adoption of practices and that practices emphasized over a long period of time were more widely adopted.

A factor in increasing 4-H Club membership for informal teaching of boys and girls, is holding the membership of the older members. A cooperative study (53) in the New England states dealt with the characteristics of 4-H Club members thruout their high-school careers as well as with the characteristics of their clubs and local leaders.

Another cooperative study (59) brought out factors influential in getting parents' cooperation in 4-H Club work for their boys and girls. The researchers concluded that informed and invited people are interested people, and interested people are cooperative people.

### Trend Studies

An excellent summary of trends in research, measurement, and evaluation in the past fifty years, including extensive bibliographical references, was written by Scates (81). Sabrosky (79) analyzed the annual reports

of the states for 1946 and prepared statistical summaries of 4-H Club work on enrolment, number and size of clubs, age of members, length of membership, reenrolment, completion of the work, local leadership, and time county extension agents devote to 4-H Club boys and girls. Grandy (39) made a similar analysis for the State of Colorado covering the twenty-year period 1926-46. Sabrosky (78) also analyzed the annual reports of the states for 1946 and prepared statistical summaries for home demonstration teaching with rural homemakers.

### Follow-up Studies

Franzén (32) summarized the responses to an opinionnaire of those who participated in the Cooperative Study of Secondary-School Standards. He found that revisions were needed especially in the sections dealing with outcomes, instructions, and teacher evaluation. An analysis (33) of the responses of 532 administrators whose schools were evaluated in the years 1940-1947, showed the need for improving various procedures.

At the college level, two follow-up studies have been reported. Knox (57) reported a sampling of eight Harvard graduating classes, distributed over the period 1880 to 1925. He found that graduation with honors was significantly related to prominence as determined by inclusion in *Who's Who in America*. A combination of scholastic class and outstanding extra-curriculum achievement supplied the best basis for predicting future success. In a follow-up study Jones (54) compared certain measures of honesty at early adolescence with honesty in adulthood. A coefficient of contingency of .37 was obtained between honesty as measured in early adolescence and adulthood. These results suggest that honesty depends upon progressive organization of inner and overt behavior and that such organization is usually well under way in late childhood or early adolescence.

Holcomb (49) made a follow-up study of 151 county extension agents on the job in Iowa. The agents found their subjectmatter training in college very helpful to them in their job of extension teaching but felt they had had insufficient preservice training in extension teaching methods, extension administration and organization, organization and teaching in 4-H Club work, adult education, program planning, office management and personnel, technical journalism, and evaluation of extension programs. Practically all of the agents favored induction training in these subjects for beginning workers.

### Surveys

There were a variety of local, state, and national surveys in the literature of this three-year period. House and Thompson (51) made a limited survey of the constitutional growth of a small sample of seventh-grade Appalachian children and found various deficiencies affecting child behavior. Hawk (45) surveyed the speech needs of 1200 elementary-school

children and found seventy students who needed special attention.

Administrative surveys included a questionnaire study (28) made by the U. S. Office of Education on the growing professional status of the public-high-school principal. Woody (98) inventoried 635 Michigan school administrators on the current problems or issues which they were facing in the state. Otto (70) found practices in the use of achievement tests, guidance in program making, departmental instruction, promotion practices, and library services in 286 public elementary schools and forty-six campus demonstration schools to be very similar. A questionnaire study (66) by Nannini showed that small town New York State school administrators consider housing, recreation, and education the main community problems; labor, inflation, government controls, housing, and education the main national problems; and atomic energy, feeding starving people, and United Nations the main international problems. Duckworth studied (24) the report forms of transfer students and found a serious lack of uniformity in grading systems. Flesher surveyed the elementary-school buildings (30) and secondary-school buildings (31) in twelve Ohio cities. He found inadequacies for both levels, tho the secondary-school buildings were newer and relatively more adequate. Butterworth and Gragg (8) reviewed an extensive list of school surveys conducted from June 1943 to June 1946.

Remmers and Davenport (76) presented data collected from the Purdue Opinion Poll for Young People showing how over 6000 high-school youngsters from thirteen states felt about such things as being a teacher, liking school, student government, work experiences, field trips, and teacher salaries.

Haas (42) received 415 replies to a questionnaire mailed to the 461 Wisconsin public secondary schools. He found that the schools allotted an "adequate" proportion of the curriculum to social studies, altho the titles of course contents followed traditional patterns. Also, he reported that a large percent of the small high-school social studies teachers were inadequately prepared.

McNelly (60) surveyed the county agricultural agent staff that was on the job in December 1947. Their average length of tenure was eight years. He also determined what they liked about their work and what they did not like.

A subcommittee (85) made a survey of working conditions of extension personnel to determine a basis for making recommendations on the improvement of working conditions and reducing turnover of personnel.

Collings (12) made a comprehensive nationwide analysis of how the home demonstration agents use their time. One hundred seventy-seven agents selected proportionately over the country and at random in a region, kept a daily record by five-minute periods for one week in the winter and one week in the summer of their activities making 2422 days of extension activities for analysis. She found that the agents spent one-fourth of their time teaching and that they worked an average of 51.5 hours a week including some Saturdays and Sundays.

Thru a survey of 666 farmers in Alabama, Leigh (58) found that the average Alabama farmer reported using twenty-three ideas about improved farming practices which he received thru several means of communication. The number of ideas the farmers used increased consistently with the amount of education they had and the size of farm. Sixty-five percent of the farmers reported getting good farming ideas from children who brought them home from school.

A nationwide radio survey (92) of attitudes of farm and small town people was made thru a stratified random sample of 2535 households in 116 counties where 4293 interviews were made. Information was also obtained on program preferences.

Social relationships studies have been made to determine the organizations in a community and how they can function in channeling extension information to the people. Hoffer (48) found that the farmers of Eaton County, Michigan received useful information about farming from many sources. The neighborhood group and the rural school district were used very often to develop extension work. According to Miller and Beagle (63) school districts were a leading unity factor in social organization in Livingston County, Michigan. The religious factor was next in importance. Niederfrank (68) studied the coordination of agencies in carrying on an effective educational program in health and nutrition in a parish in Louisiana.

Studies were made to determine needs, interests, and abilities as a basis for program planning. Handicraft and rural art activities (19) (26) were determined thru a nationwide survey including Hawaii and Puerto Rico. Many studies of local volunteer leadership have been made in the past because of the importance of the local leader in conducting extension work. The findings of these studies were summarized by Crile (16) for administrative use. Crile also prepared a bibliography (18) of extension studies and a review (17) of extension studies for 1946-47 which is a valuable source.

### Frequency Studies

A review of recent research in vocabulary development was prepared by Seegers (82) who gave a comprehensive summary of studies reported in recent years. In more specialized studies Cobb (11) compared the vocabularies of the *Basic Vocabulary of Business Letters* with the *Gregg Shorthand Dictionary* and pointed out the similarities and differences between them. Tiremen (88) conducted a study which he felt established definitely that a large percent of the error made by native Spanish-speaking children in recognizing English words in isolation was caused by failure to pronounce correctly the elements of the words. In a study of slang vocabulary in a large school, Kasser (55) analyzed changes in slang vocabulary thru comparison with the results of a similar survey conducted eleven years before. Most slang words originated with the high-school group and spread to younger children.

A vocabulary analysis of twenty pre-primers, published since 1937 and representing eleven different series, showed that recent pre-primers have lower different-word count than earlier material and that there is an increasing similarity of vocabulary in the different levels (23). Malter (61) analyzed eight available studies dealing with children's preferences for illustrative materials and found that children (a) prefer colored illustrations, (b) have a wide variety of interests in subjectmatter, (c) do not like silhouettes, and (d) have preferences subject to change. Applying the Dale-Chall formula for reading difficulty, Guckenheimer (38) found in an analysis of thirty-six pamphlets on international affairs, that 75 percent of the material is at or above the college level in difficulty. A validity of .86, based on a correlation between the composite rating of seven judges and the formula, was reported. In an analysis of the distribution of emphasis in ten physics tests and twelve physics textbooks, Weaver (96) found that the textual contents differed considerably and that the tests differed in emphasis of material and types of test items.

### Needed Research

The need for more rigorous research on the formulation and definition of major objectives of education is apparent. Present research is more opportunistic than systematic and comprehensive. The emphasis on informal, teacher-made evaluation technics represents a desirable trend, but research and development of more formal and comprehensive technics have progressed very slowly in recent years. Rationale and procedures in evaluative studies should be studied to establish more definitive criteria and principles. In surveys, trend studies, and frequency studies, a critical appraisal of procedures, criteria, and applications should be undertaken by one or more investigators to indicate improved designs and methods for these types of research studies.

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## CHAPTER IV

### Research Methods and Designs

JOSEPH LEV

**R**EFERENCES included and reviewed in this chapter were selected because they contain a discussion or illustration of some aspect of experimental design, or application of such design.

#### **Validity of Conclusions Based on Experiments**

An experiment in educational research commonly involves selection of a group of individuals and the application of some experimental procedure to these individuals, in order to obtain conclusions which are applicable to a population of which the subjects in the study are a sample. For such extension of reasoning or "induction" to be valid, it is necessary to eliminate the various possibilities of bias in the experiment. Much attention has been given in educational research to the elimination of bias in the experimental procedure. In particular, care is taken to eliminate bias on the part of the experimenter by use of objective measures. Consideration is also given to making the experimental procedure fit the situation to which the experiment applies. Less attention has been given to the possibility of bias due to the selection of individuals who are the subjects of the experiment. Clearly, the subjects of the experiment must constitute a representative sample of the population, to which the conclusions of the experiment are to be generalized. Frequently, the logic of induction is accorded recognition only at the end of the experiment when tests of significance are applied but such tests are not valid if the sample is biased. Criticism of this aspect of experimental design was voiced by Walker (49), who noted that use has not been made of available knowledge of sampling theory.

A detailed analysis of sampling bias in several psychological studies appeared in two papers by Marks. In the first of these papers, Marks (32) questioned the validity of generalization from two psychological studies because of sampling bias. It is sufficient to review his comments on one of these studies. The responses of a group of psychology students in Dartmouth to a questionnaire on race prejudice showed that such prejudice was related to the education of their parents. Since the students were all from the same college, it is possible that selective factors operating in their admission to the college provided a biased sample in relation to the total population of America, or even to some more restricted population. By means of hypothetical data, Marks showed that selective choice from a population, in which the education of parents is unrelated to racial prejudice of children, might have resulted in a sample in which a marked relationship between the factors exists. Unless random selection is used, there can be no assurance of the elimination of bias in the sample.

In a second study Marks (33) reviewed the sampling used in the revision of the Stanford-Binet scale, which was of the type known as a cluster sampling, since subjects were obtained in groups from a number of communities. Marks pointed out the overemphasis given to a few communities in the sampling. Because of the similarity among individuals within a group, there is a possibility of intraclass correlation which influences statistical calculations. Marks suggested that greater validity might have been achieved by sampling more communities with fewer cases in each community. He also gave formulas appropriate for calculation of standard errors in cluster sampling.

The importance of relating the design of experiments to the logic of induction has been especially emphasized by Fisher (17). Altho Fisher dealt mainly with agricultural experiments, the logic of his argument is universally applicable. In an experimental procedure it is often necessary to take into account the operation of variables other than the ones with which the experiment is concerned. Thus, in a comparison of teaching methods, it is often necessary to consider the variation of intelligence among pupils, and the differences of teaching ability among teachers. In the simplest design this variation can be provided for by random sampling from the total population. It is often possible, however, to assure a more satisfactory sample by sampling randomly at various levels of the variables which disturb the experiment. Thus, in comparing teaching methods, it may be desirable to sample separately from boys and girls. Fisher pointed out that such a modification of experimental design called for corresponding modification in the logic of statistical inference. Since the differences between boys and girls have been excluded from the process of randomization, these differences must also be excluded from the calculation of the standard errors used to judge the statistical significance of the comparisons made in the experiment. By the use of analysis of variance it is possible to subdivide the total variability in the data into components which are due to the operation of known variables entering into the experiment, and other components which are due to random variation and are used in tests of significance. Beginning with a simple psycho-physical experiment, Fisher described a number of experimental designs and their related tests of significance. Methods of calculation appropriate to these designs were given by Engelhart (16) and by Snedecor (40).

#### Comparison of Groups When Individuals Are Classified into Categories

Frequently, research studies are concerned with individuals who may be classified as belonging to one or another of several discrete categories, such as sex or school grade. In such studies the observations are classified into the several categories and the frequencies in the categories are determined. The analysis then proceeds in one of two directions: (a) the observed frequencies are compared with expected frequencies based on

theoretical considerations, or (b) the observed frequencies in several samples are compared with each other to determine whether they represent populations which have the same distribution.

A study using a theoretical distribution is that of Malter (30), who rated children on a test of ability to read cross-section diagrams. A theoretical distribution was constructed on the assumption that all responses were guesses, a like distribution was made up from the observations, and the two distributions were compared.

Two groups were compared in a study by Dolger and Ginandes (14). A group of children in a private school and a group of the same number in a public school were asked to offer solutions to a disciplinary situation told to them as a story. Their solutions were then classified as *constructive* or *nonconstructive*. The authors found a larger percent of constructive solutions among the private school children than among those in the public school. Some comment on the sampling may be of interest in this connection. It must be assumed that the conclusions based on the data were meant to be generalized to a population extending beyond the children in these schools. Since the sampling is limited to only two schools, all the numerous characteristics which differentiate the children of one school from those of the other specialize the populations to which generalization may be made to an unknown extent.

A more complex classification was used by Doane (13) in a study of professional curriculum requirements for high-school teaching. Colleges offering teacher-training courses were classified into three categories composing the three populations in the study. Samples from the three populations were then compared on the basis of proportions offering specific education courses. Chi-square tests of significance were calculated.

### Comparison of Two Groups on Measurable Traits

Two comparisons are made: (a) the responses of two groups to the same set of stimuli (an intelligence test, for example) or (b) the responses of a given group of individuals to two sets of stimuli. In the first instance, random samples are drawn from the two populations and the groups are compared on some statistical measure, usually the mean. In the second instance, two different samples from the given population may be used, or the two sets of stimuli may be applied to the same sample.

Several studies comparing two populations of individuals appeared in the literature. Heisler (19) compared children who read comic books with children who did not read such books, on intelligence, personality and socio-economic status. Hobson (21) compared boys and girls on primary mental traits. Leeds and Cook (28) used two groups of teachers, one superior and one inferior, to validate items on a scale for determining attitudes of teachers toward pupils.

An example of a study, in which the responses to two sets of stimuli were compared by use of a single sample, is a study by Malter (31). The

children were asked to read a diagram of a production process, both with and without the use of certain guide lines and arrows. The children were then tested on their comprehension of what appeared in the diagram under both sets of circumstances, and the mean scores of their responses were compared.

Von Eschen (46) used two designs to study the effect of supervision on teaching efficiency. In the first design, two different groups of students were selected, one to be an experimental group, and one a control group. The teachers of the experimental group were subjected to a prescribed form of supervision, whereas those of the control group were not so supervised. Mean pupil gains in achievement of the two groups were compared. In the second design, the control group of the first experiment became an experimental group the following year. Mean gains of the group for the two years were compared.

In a more complex study Gold (18) compared responses of students to various methods of teaching dental health knowledge. Two similar groups of students were chosen for the principal part of the study, which was to compare the effect of intensive training in dental health with only incidental training in the subject. From each of the principal groups a subgroup was chosen for training in a manner differing slightly from the main group. In the analysis, groups were compared in pairs, the two main groups with each other, and each main group with the subgroup drawn from it, three comparisons in all. Since four methods of instruction were used, an analysis of variance comparing all four methods at once would seem appropriate. Such an analysis would yield a sensitive test for all comparisons, and would make possible an investigation of the relationship between length of instruction and improvement in dental care.

### Comparison of Several Groups on Measurable Traits

The patterns of experimental design considered in the foregoing section on two group comparisons may be extended to the simultaneous comparison of several groups. As in the former situation, group comparisons are made: (a) the responses of several samples of individuals to the same set of stimuli, or (b) the responses of a given sample to several sets of stimuli. The statistical method applicable to these designs is the analysis of variance.

A study by Blum (3) illustrates the comparison of responses of several populations to the same stimuli. Students preparing for five professions were compared on a number of personality traits. Analysis of variance was used to test the variability among the means of groups. As is customary in such studies, comparisons were made on each trait separately, altho methods for simultaneous comparison on several traits are available.

A study by Baldwin (1) illustrates a comparison of responses of the same individuals to differing stimuli. The *Fels Parent Behavior Scales* were given to a group of mothers during the periods of pre-pregnancy, pregnancy, and post-pregnancy. The hypothesis that the means of the

scores for the three periods were equal was tested by analysis of variance. A test of the linearity of the means was also made.

### Experiments in Randomized Blocks

In order that the conclusions of an experiment comparing several procedures may be generalized to a fairly extensive population, it is frequently necessary to sample individuals in several environments; for example, schools, communities, and grades. All procedures must then be tried in each environment, for, if some procedures are tried in one environment and others in another, it will not be possible to determine whether resulting mean differences are attributable to procedural or to environmental effects. Furthermore, it is necessary to take into account differences among individuals within a given environment. The last is achieved by assigning individuals within an environment to the various procedures in a random manner. The resulting design may be called a randomized-block design, because of its parallel to agricultural experimentation, in which randomization is performed within blocks of land.

This design is well described by Burt and Lewis (7). Twenty backward readers were selected randomly from each of five schools. The children from each school were divided randomly into four equal groups, each group to be taught reading by one of four methods of instruction. At the end of the period of instruction the gain of each pupil was determined. Using the gains as scores, an analysis of variance was made, yielding mean squares due to methods of instruction, schools, method-school interaction, and variation within the twenty subgroups. The authors used the variance within subgroups as the error variance to test the significance of the differences among method means. This calculation is questionable. It is valid if the conclusions are to apply only to the five schools used in the experiment. If, however, the conclusions are to be generalized to some population of schools going beyond these five schools the variance due to interaction should have been the error variance to test the differences among methods.

Bollinger's (4) study of the impact of teachers on pupils provides an illustration of an investigation carried on in several environments without elimination of bias due to environmental differences. Certain social attitudes and aspects of social adjustment of teachers and students in the high schools of three small communities were investigated. Bollinger found that in one of these communities both teachers and students had lower scores than the corresponding groups in the remaining two communities. The differences among the scores of pupils in the three communities were then ascribed to the *impact* of the teachers. Because of the design of the experiment, this conclusion has doubtful validity. Both teacher and pupil differences may be due to community differences. The last interpretation is supported by the results of a portion of the study in which the gain of pupils in social adjustment was studied in relation to the

adjustment of teachers within a given community. Here a negative relationship was found, so that the pupils having better adjusted teachers gained somewhat less in social adjustment than pupils having teachers rated lower in social adjustment.

### The Latin Square

The randomized-block design makes possible the consideration of a source of variation in addition to the variation among the procedures being studied. It is frequently desirable to consider two or more sources of variation in addition to the basic variation among procedures. A device, which provides a method for taking into account two such sources of variation, is the Latin square. This design is described by Fisher (17) and by Snedecor (40), and has been referred to in previous reviews published in this series.

Without using the terminology commonly associated with the Latin square, Wilson (50) used this design to study the effect of length of reading material on comprehension. Essays of 300, 600, and 1200 words were prepared on each of the three topics, "Paper Today," "Paper Industry," and "History of Paper." Each of three groups of children was then asked to read essays of all three lengths, but each length associated with a different topic. After each passage was read, a comprehension score was obtained for each student. The Latin square appears as follows:

	Paper Today	Paper Industry	History of Paper
Group I	300 words	600 words	1200 words
Group II	600 words	1200 words	300 words
Group III	1200 words	300 words	600 words

The value of this design is that each of the three lengths was tested on all students, so that the variability among groups was eliminated. In addition, each length was tested on three topics, so that the bias of a particular topic was eliminated. The author failed, however, to utilize these values in the analysis of the data, since she made all comparisons by using differences of means in the nine cells. The results did not, therefore, appear as conclusive as they might if the appropriate analysis of variance had been used. Thus, in one of the topics, "Paper Today," the 1200-word essay resulted in little better comprehension than the 600-word essay, but further analysis shows that the longer essay was read by the group which was decidedly the poorest of the three. When analysis of variance is used, the variation among the means of the three

essay lengths is very significant. A supplementary analysis indicated a linear relationship between essay length and comprehension.

### Factorial Designs

An important aspect of educational research is the determination of factors which are related to individual differences. A factor is here understood to mean a method of differentiating individuals by classifying them in groups. Examples of factors are sex, national origin, and grade placement. Individuals in a sample may be classified in accordance with several factors simultaneously. Factorial studies usually proceed by obtaining a common measure for all individuals in a sample, classifying individuals on the basis of each of several factors, and comparing the means of groups within each factor separately. These studies neglect the overlap of factors, since several factors operate simultaneously to distinguish some individuals from others. This "interaction" of factors may indeed be the most interesting aspect of the study. The problem is discussed in (17: Chapter VI) and in (24).

Several examples of factorial studies follow: Smith (39) obtained scores on the *Bell Adjustment Inventory* for a group of students, and then compared means of groups in accordance with several factors, such as participation or nonparticipation in athletics, and membership or non-membership in fraternities. Stright (42) considered similar factors in relation to scholarship. Both authors found significant relationships between the factors in question and the criteria. Since the authors neglected to study interactions, certain questions remain unanswered.

Cheydleur (10) examined the relation of several factors to success in college teaching. The factors were examined separately and no account was taken of interactions. The need for examining interactions is illustrated clearly by the two factors: (a) having professorial rank, and (b) not doing graduate work. Both of these were related to good teaching, and surely interact.

Brownell (5), who investigated two factors related to teaching subtraction, did consider interactions. One factor consists of two methods of teaching borrowing, and the other of teaching either method mechanically or by rationalizing the procedure. The analysis of data dealt with the subjects as four groups, distinguished by both the method of subtraction and the method of instruction. Thus, the analysis may be said to have dealt only with interactions, and to have neglected main effects. Comparisons were made by using differences of means between all possible pairs of groups. It is worth while noting that the methods of analysis of variance would have provided information regarding both main effects and interactions with a more sensitive test of each. The value of investigating interactions is further emphasized by Brownell (6: p. 111) in his critical comments on a later study of the same problem.

Schroeder (37) investigated the teaching of archery using three groups

of students all of whom received six lessons in the skill. Three ranges of thirty, forty, and fifty yards were used, all students shooting at all three ranges at each lesson in varying order for different groups and different days. The experimental design permitted an analysis of the following four factors and their interactions: (a) groups, (b) test halves (the first three lessons against the last three), (c) order of shooting at a given range within a given lesson, and (d) length of range. Information was obtained of main effects and first, second, and third order interactions by use of analysis of variance.

### The "Split-Plot" Design

This design owes its title to a type of agricultural experiment in which several procedures are compared in a set of plots. In addition to comparing one plot with another, the plots are divided into two or more portions which are treated differently, so that intraplot comparisons can be made. There are then, in fact, two parallel experiments with different estimates of error (40: p. 309).

The split-plot design was used by Vergara (45) in a study comparing the comprehension of poetry in oral presentation with its comprehension when read silently. Sixteen poems of four types and two groups of subjects were selected. Each group read eight of the poems silently and listened to an oral presentation of the remaining eight. Thus, each poem had both an oral and silent presentation and, correspondingly, two scores. Two types of comparisons were then possible. Using the sum of the oral and silent scores for each poem it was possible to compare the mean scores of the four types of poem. Using the differences between oral and silent scores it was possible to compare oral with the silent presentation. The two comparisons used different estimates of error.

### Use of Concomitant Measures in Group Comparisons

In the previous sections of this chapter experimental designs were considered in which all subjects are scored on a measurable trait and are then grouped into several categorical classes in accordance with one or more criteria of classification. These criteria of classification were considered as sources of variation in the data. It is often necessary to consider sources of variation which are based on measurable traits rather than categorical classes. Thus, in comparing educational achievement of several groups, it is desirable to consider the intelligence scores of individuals in the groups. The appropriate method of analysis in this situation is the analysis of covariance.

Johnson and Tsao (24) used two concomitant measures in a factorial study of educational achievement of high-school students. The purpose of the study was to investigate the effect of four factors on scores in a test of scholastic achievement given at the end of the school year. The factors

were grade status, scholastic status, sex, and rank order within each grade-scholastic-sex subgroup. In addition to the scores on the achievement test given at the end of the school year, scores on the same test given at the beginning of the year and mental age scores were obtained for all subjects. The latter two measures were used to eliminate the component of variability in the final scores due to these measures from the group comparison required in the study of the various factors. All main effects and interactions were examined.

Moore (34) used chronological age and mental age as concomitant measures in a comparison of vocabularies of orphanage and nonorphanage children. Since the two groups differed considerably in both chronological and mental age, it was necessary to eliminate these sources of variation before a fair comparison of vocabularies was possible.

Johnson and Hoyt (23) compared two groups on their ability to learn physics. Three additional measures, consisting of scores on the *American Council on Education Psychological Examination*, elementary mathematics, and honor-point ratio, were obtained for each individual. The two groups were then matched on the latter three variables in such a way, that comparison between the groups could be made on each set of three scores based on these variables. The matching procedure can be viewed geometrically if coordinate axes are set up in three dimensional space and scales corresponding to the matching variables are set up on these axes. A set of three scores is then a point in this space, and the groups can be matched at each point. By examining sets of points, regions of significance and non-significance can be laid out. The matching procedure was achieved by calculating regression equations after the data had been obtained, rather than by matching at the beginning of the experiment.

### Relations between Two Measurable Traits

The study of relations between two traits is so standard a procedure of research that it seems scarcely necessary to report on it in this review. Some of the applications may, however, be of interest. The applications reviewed here are of two kinds: (a) those dealing with prediction, and (b) those dealing with test validation.

The following studies dealt with prediction. By correlating judges' estimates of item difficulties with their true difficulties, Tinkelman (44) found that judges were quite successful in predicting item difficulty. Stalnaker (41) studied the relationship of achievement in college with scores on an entrance examination. Thorndike (43) correlated scores on the *College Board Aptitude Test* with grades on intelligence tests taken at various times prior to college entrance to determine the effect of lapse of time on the estimation of intelligence. Lantz (27) investigated the value of informing teachers of achievement to be expected of children when this expectation is based on tests administered to the pupils. Jayne (22) carried out an experiment in which ten teachers taught the same lesson and studied pupil gain in relation to the procedures of the teachers.

The following studies dealt with test validation. In order to validate a paper-and-pencil test on superstitions, Zapf (51) created a situation in which responses of students to stimuli associated with various superstitions could be observed and scored. The students were instructed to enter a room in which the stimuli were present and their behavior was observed without their knowledge. Dyer (15) used actual translations made by students as a criterion to validate objective tests of ability to translate German into English.

### Use of Multiple Measures in Prediction

In an effort to find some means of predicting behavior, many measures are often made and multiple regression estimates are calculated to synthesize the diverse measures.

Lins (29) studied the possibility of predicting teaching efficiency from information available during and prior to attendance at college. Numerous measures were obtained for each of fifty-eight teachers from the application blanks filled out at entrance to college, from intelligence tests, from an autobiography, and from an analysis of teaching fitness as shown during the senior year. Three criteria of teaching efficiency were used: (a) a combined rating based on opinions of supervisors and of observers from the school of education; (b) a rating based on comments of students; and (c) a measure of gain of pupils in educational achievement. Regression equations were calculated between the measures of prediction and each of the criteria. The possibility of correlating all criteria simultaneously with the predictors by use of canonical correlations suggests itself here.

In a companion study using the same teachers and the same criteria as Lins, Von Haden (47) studied the prediction of teaching efficiency by use of subjective measures. These measures were obtained from comments of interviewers, instructors and supervisors; from an analysis of stenographic reports of interviews; from autobiographies; and from personal data. Regression equations were calculated. In another companion study, Jones (25) used objective measures based on data available at entrance to college and on college grades to predict teaching efficiency. Hellfritsch (20) made a factor analysis of the measures used by Lins, Von Haden, and Jones. Carter and Dudek (9) used several measures in a study of plane navigators' efficiency. Regression equations were calculated using as a criterion errors in bringing the plane to a required point.

Detchen (12) investigated the value of items in the *Kuder Preference Record* in predicting success on a social-science comprehensive examination given at the University of Chicago. The items in the test were keyed by comparing responses of students who did well to responses of those who did poorly on the social-science examination. The resulting test was then included in a test battery to predict success in the examination. An important aspect of Detchen's work is the fact that she tested her key on a sample other than the one used to establish the key. This procedure was necessary, since the key contained many sampling errors and

could not have been regarded as valid for the population unless tested further. A need for similar testing arises in the studies of teaching efficiency referred to above. The authors selected those groups of measures which had highest multiple correlation with the criteria, but these multiple correlations were highest only in the sample, and additional study is needed to determine whether they are highest in the population.

### Comparison of Groups by Use of Multiple Measures

It is common in studies which compare two or more groups to obtain several measures on each individual, but to compare the groups on each measure separately. However, procedures are available for comparing the groups on several measures at once.

Lins (29) studied the relationship of a set of measures, which included college-entrance tests and high-school records, to admission to a school of education at the end of the second year at college. There were two groups to be distinguished, those admitted to the school of education and those not admitted. By use of biserial correlations between the two groups and the various predictors, Lins obtained a regression equation to predict admission to the school.

Baten (2) used scores based on judges' opinions of color, mealiness, texture, and flavor to distinguish between types of potatoes. Using discriminant function analysis, he obtained a set of weights by which the scores can be combined to obtain best discrimination.

The problem of discriminating between more than two groups was considered by Rostker (36) in a study of factors relating to teaching ability. Teachers of twenty-four classes were measured on many traits. Pupil gain as measured by initial and final tests was the criterion in the study. In order to determine whether the differences in pupil gain were related to the teacher measures, average pupil gain was calculated for each class, and the averages were correlated with the set of teacher measures. To eliminate variation due to differences in ability among pupils in the various classes, a regression equation was calculated for pupil gain and measures of ability. Pupil gain was then measured in terms of deviations from the regression estimates. Companion studies similar to that of Rostker but using different measures were carried out by Rolfe (35) and La Duke (26). Rostker considered each class as an individual and so had only twenty-four cases to work with, a small number for a multivariate study. Actually there were as many cases as pupils in the classes and, consequently, many more degrees of freedom for testing significance.

### Sample Design in Surveys

Much greater care is often exercised in obtaining a sample when a survey is carried out than in the usual research study. An outstanding example of a carefully planned survey is that made by the U. S. Office of Education

in 1946 to determine higher educational enrolments, and described by Cornell (11). The survey was based on a sample of approximately one-fifth of all institutions providing higher education in the United States. The institutions in the sample were obtained by setting up strata on the basis of category of school and size within category, and then sampling randomly within the strata. By use of mathematical formulas and information regarding enrolments obtained from previous surveys, the number of institutions to be sampled from each stratum was determined, so as to provide standard errors of preassigned accuracy.

The application of sampling methods to public-opinion polls was described by Cantril (8). Smith (38) combined survey methods with those of testing hypotheses. The purpose of the study was to determine the relationship between level of knowledge and liberal opinion. A sample of 6000 persons was obtained. For each person, level of knowledge was measured by response to four questions based on current events, and liberal opinion by response to four opinion questions. The relationship between the two measures was studied within groups which were homogeneous both as to occupation and income.

### Sequential Sampling

Sequential sampling provides a modification of the usual sampling procedure, since by this method cases are obtained sequentially, one by one, or in groups. When applied to testing a hypothesis, the hypothesis is formulated and two probabilities are assigned in advance of the sampling procedure. The probabilities are due to errors in (a) rejecting the hypothesis when it is true, and (b) accepting the hypothesis when it is false. These probabilities are arbitrary, and are based on the practical importance of these errors. On the basis of the hypothesis and the pre-assigned probabilities, certain calculations are made at each stage of the sampling sequence, i.e. after each observation or groups of observations. The calculations lead to one of three decisions: (a) reject the hypothesis, (b) accept the hypothesis, (c) continue sampling. It has been found that sequential sampling reduces greatly the number of cases required for a decision as compared to ordinary sampling. The theory and numerous applications were described by Wald (48).

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## CHAPTER V

### Observational Methods of Research

SAUL B. SELLS

THE three-year period covered by this chapter was deeply affected by the war, one important effect of which is apparent in the displacement of research personnel during that period. Nevertheless a considerable quantity of research in all fields was published. The studies summarized here appear to make contributions to or to illustrate particular aspects of observational research methodology. This chapter, altho organized somewhat differently, continues the previous review of observational methods by Sells and Travers (115).

#### Direct Observation Techniques

A wide variety of forms of direct observation for collection of basic data has been noted. Some investigators use written documents or recorded factual material as a source with appropriate technics of recording and analyzing. Others are based on observation of human behavior in action, in actual real-life, clinical, and experimental situations. Systematic studies employing direct observation of behavior have been confined mostly to infants and young children. Much useful information might be obtained by extension of these technics to other groups.

It should be noted, however, that the value of any technic of direct observation as a definitive research method depends on the rigor with which it is applied. Direct observation and especially records from direct observation are subjective. Reliability of data, or reproducibility, can be increased by standardization of procedure, by the proper use of codes or recording schedules having formally defined categories of classification, by the use of apparatus aids, such as moving tapes or stop watches for time samples, and by the use of additional observers to check on the original observer. The value of results based on these methods must be judged in part by the evidence of reliability of observations. The representativeness of the sample of population observed must similarly be evaluated.

It will be noted that many observational studies are either delinquent in their consideration of the aforementioned restrictions or else they are frankly preliminary and exploratory in nature. Some of the studies reported below treat reliability adequately. Few have remarks on the statistical adequacy of the sample population. However, each of them has some value as a representative of a particular observational procedure, and it is on this basis primarily that selection was made.

### Sociological-Psychological Survey

Stroup's (119) study of the Jehovah's Witnesses was an attempt to understand this movement in its historical and social context. Using original observations of public and private practices of the sect, and many of their publications, he described the history of the movement, its organization and hierarchy, and the literature, beliefs, attitudes, and conversion experiences of the Witnesses.

### Content Analyses of Documents

Davison (31) and Dallin (29) analyzed Soviet propaganda by content analysis of selections from the Soviet press. Davison selected a sample of four Russian-controlled papers for fifteen days, tabulating the number of items published according to six preselected propaganda themes. He compared these data with the total material available in the news service bureaus. Dallin analyzed the increasing proportion of anti-U. S. attitudes manifested in Soviet "news" articles and editorials. Dollard and Mowrer (33) outlined a method of measuring tension in written documents.

### Analysis of Paintings

Alscherler and Hattwick (1) obtained paintings and samples of use of other creative media such as crayon work, clay, blockbuilding, and dramatic play for 150 children, two to four years of age, from five public nursery schools in Winnetka, Illinois. They studied the entire group for a year, and planned to follow up a number further. Analyses of these data were compared with expression of characteristic feelings in overt behavior. They found evidence of comparable forms of expression of universal experiences by children of different social backgrounds. Elkisch (36) studied a sample of 2200 drawings and paintings by twenty-five children. She also selected eight children, according to their group popularity by sociometric methods, whose art products were analyzed in detail. This study is interesting because of the definite analytic criteria developed in terms of rhythm *vs.* rule, complexity *vs.* simplicity, expansion *vs.* compression, integration *vs.* disintegration, and realism *vs.* symbolism. Waehner (126) studied the drawings of fifty-five college students. Both spontaneous and assigned drawings were scored according to content and to preference for certain types of formal expression (size of paper, size of form elements, quality of lines, organization of form, shading, etc.). A psychologist, a Rorschach expert and teachers then matched the personality sketches, based on these analyses, with the drawings. A high degree of identification was reported.

### Factual Studies

Morton (95) analyzed the questions regarding aviation asked by 3262 children in Grades I to VIII, by tabulating the proportion of arithmetical

questions concerned with number, size, and time. From this he drew conclusions regarding the mathematical interests of boys and girls at various elementary-grade levels. Baker (5) collected 9280 questions from 1402 children in Grades III to VI in sixteen cities. She analyzed them by content and considered their implications for the elementary-school curriculum. Masuoka (87) compared records of food purchases of 100 Hawaiian-Japanese families for thirty consecutive days in 1933-34 with (a) records of foods purchased by rural Hawaiians in 1928 and (b) data for Japanese in Japan. Changes in diet for the Hawaiian group were found to be in the direction of adoption of American foods.

### Recording of Speech

Irwin (58) and Chen and Irwin (23) have recorded speech-sound data of infants using the International Phonetic Alphabet. Irwin presented statistical evidence of the reliability of the method, particularly for the vowel sounds. Chen and Irwin showed that at two and one-half years the infant possesses nearly the full complement of adult vowel sounds but only about two-thirds of the consonant types. Bossard (17) made transcripts of family conversations at meal time for thirty-five families and supplemented these with interviews. From these data he developed analyses concerning (a) range and meaning of family vocabulary, (b) levels of language, (c) language as a social index of occupation, religion, and social class, (d) family idiosyncrasies in communication (i.e., peculiarities, private meanings, taboos), (e) patterns of conversation (e.g., subjective, objective) and (f) speech characteristics and pronunciation. Johnson and Colley (63) had twenty stutterers read a 1000-word, phonetically edited passage, while two concealed observers recorded the duration of each stuttered movement on a moving tape. They studied the correlation between frequency and duration of stuttering movements.

### Case Histories: Individual Case and Exploratory Observations

Many valuable facts, relationships, and skilled insights are frequently stimulated by observations made incidentally in other than purely research activities. The following examples were selected to illustrate the importance of such reports. Axline and Rogers (4) reported a detailed case history revealing how a skilful teacher-therapist treated a maladjusted 6-year-old boy. Clark and Barker (24) presented the verbal report of an intelligent 18-year-old Negro "zoot suiter" of his participation in the Harlem riot of 1943. Dukes (34) described two cases to illustrate the devastating effect that the (wartime) disruption of family life can have on children and their parents. Anderson (2) cited the clinical findings of eighteen aphasic cases, illustrating two types, (a) in which linguistic difficulty interfered with the development of speech, and (b) in which disorders were observed producing linguistic regression. Goldfarb (48) made ex-

tensive investigations of the life histories of fifteen adolescent children in institutions. His results supported his previous conclusions that infant deprivation results in a basic defect of total personality especially in concept formation and as an attitude of passivity and emotional apathy. The reports of Knapp and Cambria (75) and Stevens (117) used case records as their source.

Peller (101) published a list of over 100 items designed to aid teachers of children from two and one-half to six years in observing significant behavior symptoms.

### Observational Research Studies

Muste and Sharpe (96) studied preschool children in two situations in order to observe aggressive behavior. Their results cover technics used by children responding to aggression and the relation of frequency and type of aggressive behavior to age, sex, and environmental background. Wellman and McCandless (128) used two technics, short sample records of child behavior and a method called "following the teacher for a full day," supplemented by intelligence and vocabulary tests, in a study of thirty-four preschool children. Newman (97) developed technics for describing the behavior of up to 100 junior-high-school pupils of each sex. Noon-hour playground behavior was rated by three judges using a composite scale of behavior patterns, each analytically characterized by paired opposites and an integral scale consisting of gross behavior characterizations of the same traits. Clubhouse behavior was rated by four judges on a scale consisting of twenty characteristics described in terms of the two extremes and the middle of a seven-point scale, and twenty other traits described by a single adjective or phrase of each extreme. These ratings were supplemented by narrative and conference records on the behavior situations. Her report covers reliability data for the ratings and examples of the scales used. Lannert and Ullman (78) made a valuable study of piano sight reading by observing nine advanced students play unfamiliar selections. Their analysis resulted in some important conclusions concerning the development of skill in reading musical scores. Van Bruggen (123) studied factors affecting regularity of the flow of words in written compositions by observing and recording mechanically the time required for writing each word, and the number and length of pauses between words, in three types of composition written by eighty-four pupils in Grades VII, VIII and IX. These observations were interpreted in relation to kind of composition, M.A., C.A., and scores on reading, vocabulary, and spelling tests, as well as personality measures.

### Analysis of Radio Programs

Katz and Eisenberg (67) and Peatman and Hallonquist (100) reported studies using the *Lazarsfeld-Stanton Program Analyzer Test*. This method

enables each member of an audience to indicate continuously by an individual signal, objectively recorded, his like or dislike for every moment and part of a radio program. Katz and Eisenberg found that listeners do not reject educational programs as such, but want them to be entertaining.

### Longitudinal Studies—Biography

This heading implies two different approaches; yet each involves consideration of the development of the individual in the perspective of his life span. Gesell, Ilg, Ames, and Bullis (47) have produced an important longitudinal study, based on periodic clinical examination of fifty children from a prosperous American community, at five, five and one-half, six, seven, eight, and nine years. A smaller number of ten-year-olds were examined. The investigation covered a wide range of individual and social behavior, which was treated in terms of growth gradients and growth trends. Koshuk (76) made a preliminary report of 500 developmental records collected over a three-year period in two California nursery schools attended by children of employed mothers. The records included a pre-entrance interview with the mother, observational notes and semester reports by teachers, and an interview with the mother when the child was withdrawn from the nursery school. Her analysis was concerned primarily with changes in home behavior and social adjustment.

Hill and Ackiss (53) suggested the use of the life history method, based on detailed, intimate, insight interviews, as a method of understanding the attitudes, feelings, and beliefs of special groups, and obtaining a more complete understanding of the dynamics of race relations in our society. They presented three condensed life histories together with their analysis of each in reference to the problems of an all-Negro community. They believe that this methodology especially lends itself to the study of race relations, since it focuses attention on the irrational, emotional, and psychic quality of racial attitudes; that it bridges the gap between the factual community survey and the personality-culture study.

Kelley (70) discussed the autobiography as a useful diagnostic and therapeutic tool in psychiatry. It is a source of information concerning the individual; it has diagnostic value with reference to the quantity and form of the patient's writing; it focuses on the patient's problems; it is an instrument of catharsis and helps the individual know that he is helping himself.

### Ratings, Rating Judgments, and Rating Scales

While direct observation frequently involves judgments by the observer, these judgments are primarily descriptive and classificatory rather than evaluative. Rating judgments involve observation as a source of information, but the emphasis is on evaluation. A critical appraisal of rating judgments as an instrument of research must recognize the requirements

of reliability and sampling. These two problems are interrelated in ratings, inasmuch as one source of unreliability of ratings is the peculiar set of biases occurring between samples. These include (a) differences in sample composition in attributes of members, (b) differences in standards or criteria employed by different raters in relations to different samples, (c) different biases and halos affecting raters with regard to different samples. The validity of ratings, however, is the most critical problem. This is the question of identification of the attribute or function rated with the true representation of the attribute or function, and is usually demonstrated by correlating the ratings with a suitable criterion.

### Assessment of Men

The psychological division of the Office of Strategic Services, under the leadership of Henry A. Murray, developed valuable technics of assessment by which personnel were evaluated and selected for wartime assignments of highest requirements and responsibility. One of the significant aspects of the assessment program was the emphasis on an interpretive synthesis of the whole person, in contrast to the elementaristic approach so much in vogue. MacKinnon's report (82) describes the method.

### Rating Scales

Metfessel (91) proposed that a scale of cardinal numbers be used in expressing comparative judgments so that the subject either actually or symbolically manipulates units of the ratio scale of cardinal numbers in expressing his judgments of quantitative relations among the items on a given dimension. He claimed that this method causes comparative judgments to be made with greater sensitivity than is the case with ordinal scales and individual differences are likely to be given more consideration by judges using this method.

Weinland (127) outlined a technic for improving the reliability of rating scales by obtaining descriptive words for rating scales, which will be in the workers' language, and will be conducive to using the whole scale without overloading at the average. The method involves first writing a list of descriptive terms for a particular characteristic, then evaluating each word by placing it on a nine-point scale, and finally selecting the best words for a five-point scale at the approximate relative positions of two, four, six, and eight. Kelly (71) presented a useful technical report on the development of a scale for rating pilot competency. He described the method of developing the scale and the data on item interrelationships. The preliminary "man-to-man" graphic scale covering skill, emotional stability, and judgment was discarded because of high intercorrelations between traits, indicating lack of independence. The final scale combined the best points of several other attempts into a fourteen-item graphic scale. A factor analysis of item intercorrelations of this scale showed that three

factors, (a) skill, (b) judgment, and (c) emotional control account substantially for all of the variance.

### Rating of Applicants for Positions

McCoy's (88) comprehensive report described trends and research in evaluation and rating of Federal Civil Service unassembled examinations. Job analysis precedes and forms a basis for examining technic, which considers applicant's training and experience records, supplemented by various documentary and interview evidence. Examiners evaluate applications numerically on rating schedules. The current emphasis is on quality rather than quantity of qualifications. A refinement of procedure was the establishment of rating factors, based on the specific skills or abilities needed. Quality ratings on a graduated scale were assigned to applicants on rating factors established on the rating schedule for each position. Brody (20) described a method he developed for judging candidates by observing them in unsupervised group discussion. Ten to twelve candidates are observed at a time, and each may be asked to speak for three to five minutes on some selected topic, following which all participate in group discussion. The employer-interviewer is free from participation and may devote all his attention to observing and rating candidates. Brody cites how the New York City Department of Health has used this group method, judging candidates for appearance, manner of speech, attitude toward the group, leadership, contribution to group performance, and scientific approach.

### Rating of Teachers

Seagoe (114) found that the success of twenty-five teachers, after two years of service, measured by ratings by school administrators directly over them, was correlated with test scores on personality, emphasizing mental health, obtained while they were in training. Prognostic tests of teaching ability given at the same time showed no predictive ability. She also found relatively high correlations with the criterion for training teachers' judgments of teaching success, but not for grade-point ratio. Von Haden (125) used a composite of five supervisory ratings, pupil evaluations, and pupil gains as criteria, and interviews, digests of interviews, autobiographies, and instructors' and supervisors' ratings during teacher training as predictors, in a study of fifty-eight women teachers in first-year positions. He found that subjective personal data correlate most highly with supervisory ratings of teaching success, but are not closely associated with objective measures of teaching effectiveness as indicated by pupil evaluations and pupil gains. Barker (7) used personal interviews and case studies, as well as ratings by superiors in a study of personality adjustment of teachers. School principals in consultation with their general supervisor selected three teachers from each of twenty schools, on the basis of (a) the best teacher, (b) an average teacher, and (c) a below-average

teacher. Her findings showed a marked pattern of relationship of adjustment measures to efficiency in teaching.

### Merit Ratings of Personnel

Probst (106) described his *Probst Rating System* with examples for a variety of occupations, together with technical treatment of item selection, foreign translations, oral interviews, and experimental procedures. Ryan (111) argued that the logical difficulties and practical inadequacies of graphic rating scales with numerical scoring are bad enough to offset any advantages claimed for them, and suggested a simple scale for merit rating until more adequate means of measuring an employee's value can be found. This is a three-point scale ranging from outstanding thru average to poor, restricting extremes to the upper and lower 10 percent. This type of scale employs judgments which can be made with some confidence, altho it has compensating shortcomings in the massing of the middle 80 percent. It can be refined somewhat by requiring separate judgments on special qualifications and abilities, such as dependability, specialized technical knowledge, ability to instruct others, and ability to get along with others. Mahler (84) prepared an annotated bibliography covering employee rating methods, administration of merit-rating programs, types of rating methods, and research and reports on the use of merit ratings. In another paper Mahler (83) reported a survey of current practices in employee rating in 125 companies, in which most of them use a scale method. A total of 131 different traits were listed on these scales, which generally were individual scales using from one to thirty-three traits which were often poorly defined and overlapping. The number of degrees for rating each trait ranged from three to sixteen. Ferguson (39) developed an employee merit-rating system for a large company. This system was especially designed to measure the factors having a direct bearing on the success or failure of a group of workers on identical jobs. He described the development of the system and the experimental work of validation.

### Ratings of Courses by Students

Barkley (8), Fowler (41), Marsh (85), Savage (113), and Taylor (122) investigated the appraisal of courses by students. In general, favorable ratings predominate. These ratings seem to be unrelated to scholastic aptitude, altho Savage found a tendency toward less approval associated with low grades. Fowler reported that students generally rated their instructors higher than the instructors rated themselves. Both students and instructors believed the ratings "served a good purpose." Taylor and his associates discussed arguments for and against such ratings which they believe valuable for the teacher and the administration but reported that the majority of the Smith College faculty recently voted adversely on this issue.

### Ratings of Social and Personal Factors

Anderson (3) had the male and female heads of 344 New York farm families rate their own families on a four-point scale with respect to two indicators of social status and three indicators of social participation. Ratings of status were higher than those of participation. Analysis of ratings in relation to objective measures of social status and social participation showed that most participation and leadership activities are not only carried out on the basis of social standing in the community, economic position, tenure status, and family maturity, but also as an expression of the opinion of the family about its own social position. Remmers and Kerr (109) measured cultural, aesthetic, and economic aspects of the home environment of 16,445 eighth-grade children in forty-two cities in twenty states by means of the *American Home Scale*. The cities chosen were approximately equally spaced in Thorndike's G scale. Correlations of city averages with Thorndike's G (goodness of living), I (income), and P (personality) indexes are low and not significantly different from zero. The authors believe that the *American Home Scale* has higher face validity and measures more directly and validly goodness of living, functional income, and personal factors than do the Thorndike scales. The treatment of validity in this paper is of interest inasmuch as there is no independent criterion by which to judge the conclusion. Kaufman (68) studied biases in ratings in an interesting fashion. He had fourteen individuals judge the prestige rank of members of a New York rural community and studied the judgments with respect to agreement with judgments of other raters, objectivity and discrimination in judgment, and biases evident in judgments. Results showed that despite high correlations of individual with composite group judgments, individual objectivity (ability to distinguish between personal likes and dislikes and the way in which a person is regarded in the community) varied considerably, and to some extent the judge's objectivity seemed to be influenced by his own prestige rank. Individual bias also varied considerably, apparently heavily determined by the judge's attitude toward the social group with which the person rated was affiliated. Goodenough (49) had ten men and ten women judge the sex of 115 high-school students from specimens of their handwriting and report degree of confidence of the judgment on a three-point scale. Identification judgments were correct in about two-thirds of the cases, with no sex difference in success of judgment. However, all women judges' confidence judgments exceeded the median for the men, and a positive correlation was found for both sexes between accuracy of judgment and confidence. Rokeach (110) studied factors affecting judgments of beauty by college women. Using five separate groups, he had each subject rate herself and each other member of her group on beauty. He obtained three scores for each person: (a) average rating by all others in group, (b) self rating, (c) average rating attributed to others. The results indicate in part that persons below the average of the group tend to overestimate their own

beauty, that those who have insight into their own possession of beauty tend to be objective in rating others, and those who have a high degree of beauty tend to be objective in rating others regardless of degree of insight. Mitchell (93) presented two high-school classes numbering seventy-five with a schedule entitled "Types of Persons I Have Met." This list contained forty-four classifications, such as Alibi-Ike, Goody-Goody, Honest Type, Pussy-Foot, and Tough. Each student was asked to write in each category the name of a classmate who best fitted it. He found considerable agreement on judgments in both classes which he interpreted in terms of the tendency for a person's social stimulus value to be consistent. Jacobson (61) divided a freshman class of 285 women into eleven groups and had each member evaluate her group mates on appearance and behavior. She analyzed 9076 responses into forty-nine subtopics and classified these into five categories. The result was that responses of a psychological nature were most frequent, with grooming second, physical characteristics third, clothing fourth, and intelligence fifth. Favorable evaluations were more frequent than unfavorable or neutral ones.

### Sociometric Ratings

Sociometry is not a new method. However, the wide applicability and adoption of sociometric measures in the study of problems of group dynamics is one of the conspicuous occurrences of the current period. Moreno (94), its originator, discussed the contributions of sociometry to research methodology in sociology in the study of intergroup relations, as distinguished from its twin study of interpersonal relations. The following papers by Potashin (104), Olson (99), Bonney (15) (16), Blanchard (12), and Jacobs (60) are concerned with studies of interpersonal relations. In her study of children's friendships, Potashin defined friends as pairs of children in which each gives to the other the highest choice in a sociometric test in a classroom, while nonfriends are pairs in which one gives the other his highest choice, but the latter does not reciprocate. She compared friends with nonfriends and found that sociological factors are of little significance in determining friendships, while physical or intellectual similarity are even less significant; a child who is one of a pair of friends is usually well accepted by the group while a nonfriend is not so well accepted. Friends also seemed to participate in group activity more and to require less adult direction. Olson reported a highly interesting experiment in which a sociometric analysis of a third-grade class, supplemented by studies of family and community relations, was the basis for a successful effort to improve human relations among the children in the classroom. The study also gave rise to a conclusion that children's social relations in a classroom have deep roots in community and family living as well as in the physical, mental, and emotional differences among the children. Bonney asked 100 sixth-grade children to indicate individually with whom they played most often, and those whom they would prefer to have on their

side for a quiz-kid program. He studied the amount of reciprocating between those chosen rarely and those chosen frequently. The tendency of the low group to choose high group more often was more pronounced in choice of quiz-kid teammate than in choice of playmate. Jacobs asked seventeen girls in the same office, individually, to name those with whom they would prefer to work in close proximity. The tabulated results revealed certain attractions and repulsions among the girls which were not known to the management of the firm, but which nevertheless probably affected office morale and productivity.

### Interviews

Perhaps the most ambitious and scientifically rigorous investigation of human behavior ever undertaken using the interview as a method of data collection is the so-called Kinsey (72) survey of sex behavior. At the time of this report, 10,500 case histories were completed, based on first-hand interviews with persons "of wide social range, of all ages, and diversity of educational, occupational, religious, and rural-urban backgrounds."

The interview is a basic method of research, as above, as well as of evaluation, guidance, and therapy. The following group of studies illustrates methodological aspects of the interview method.

#### Projective Technic in Interviewing

Pepinsky (102) described how he used a lithograph of a bleak landscape on the wall in his office in the manner of a Rorschach card. As a counselor, he directed the client's attention to the picture during the course of a counseling interview, without making the client suspicious or hostile. He claimed that this technic provides a release of tension for the subject and a possibility of diagnosis by uncovering hidden motives. Rautman and Brower (108) used ten pictures from the *Thematic Apperception Test* in interviewing 536 public-school pupils in Grades III to VI and their twenty teachers in December 1943. Each pupil or teacher wrote a brief story about each picture and answered the following questions: (a) What is happening? (b) How are they feeling? (c) How will it end? The resulting data were examined for evidence of war-inspired themes. Symonds (121) used forty-two pictures, especially drawn for the study, each containing at least one adolescent figure with which an adolescent might identify himself. He secured stories on each picture from twenty normal boys and twenty normal girls in junior- and senior-high school and tabulated the number of themes presented. In this preliminary report he stated that the count of themes presented should serve as normative data against which to compare fantasy productions of individuals and groups.

#### Interview in Casework

Voiland, Gundelach, and Corner (124) formulated a casework approach intended to assist the caseworker in the diagnosis and treatment of people

and their problems from the very beginning of casework. They stressed the importance of developing rapport in the first interview and the need for meeting the client on his own ground. Kay and Schick (69) described the "role-practice" method of training interviewers in developing skill and insight. A study of social conflict in a community of mixed ethnic groups required that interviewers obtain information with regard to informants' intimate, private attitudes. Interviewers were trained by practicing, in succession, each of several roles representing different approaches of the interviewer, i.e., friendly, inquirer, stranger, analyst.

### Interview in Evaluation

Newman, Bobbitt, and Cameron (98) reported reliabilities of from .83 to .85 in independent interview ratings by two psychologists and a psychiatrist with 399 Coast Guard Reserve officer candidates and 137 SPAR officer candidates. The bases of evaluation were complex and covered (a) ability to pass academic training, (b) ability to withstand psychological pressures and tensions of the training program, and (c) ability to withstand the trauma of combat and demands of service life. Ratings were on a thirteen-point scale. The report covers factors influencing reliability.

### Patterned Interview

McMurtry (89) cited several studies which revealed the extent to which interviewers using the patterned interview were able to predict ultimate job success. The patterned interview usually is a printed form containing specific items to be covered and providing a uniform method of recording information and rating the interviewee's qualifications. The principal advantage of the patterned interview is that it eliminates much of the guess-work and provides greater uniformity of results.

### Interviews in Research

Huang and Lee (56) used interviews in an experimental study of child animism. They asked twenty children from six years to eight years seven months questions about a dog, tree, river, stone, pencil, bicycle, ball, automobile, watch, and the moon. The children indicated whether they believed the object was living, had life, felt pain when pricked, was capable of wanting, could be good, had anything it must do (function), and performed this purposefully; then they amplified this statement. Results were analyzed in terms of animistic beliefs and in relation to age. Duvall (35) interviewed ten fiancées and sixty-seven wives of servicemen to study the effect of wartime separation of women. He found that loneliness was mentioned most and was a function of the degree of social participation, the more active wives being less lonely. Witty, Coomer, and McBean (130) secured interviews with children

in kindergarten and the first three grades, and questionnaires for children in Grades IV thru VIII, totaling 7879, to ascertain their favorite books or stories. The children's selections agreed closely with lists of books selected by adults. Maturation of interests was observed from grade to grade. The report lists preferred books, with rank awarded to each, for kindergarten, primary, intermediate, and upper grades. Jones and Arrington (64) made a qualitative and quantitative study of the explanations of physical phenomena given by 161 Negro and 134 white children in Grades III to VIII to find whether there is justification for a belief that Negroes are more superstitious than whites. The results did not support this hypothesis; very few answers in either group indicated belief in either the supernatural or in superstitions.

### Questionnaires

The questionnaire is undoubtedly the most frequently used of all observational technics, having obvious advantages in administrative economy of time, money, and effort over other methods. However, savings accomplished by this method are frequently made at the sacrifice of sincerity, completeness, reliability of response, and validity of interpretation. Technics of questionnaire construction and standardization are well established. It appears that they are too often disregarded, however, because they involve expenditure of time, effort, and skill which compensate for savings accomplished in administration. Unfortunately many studies are published which use questionnaires uncritically and without adequate preparation.

### Studies of Questionnaire Technic

Marsh (86) demonstrated the influence of set or attitude created thru verbal instructions upon responses to questionnaires. He gave two groups of college students a fifty-seven item form entitled "Campus Issues Inquiry." One group was instructed to judge the items impersonally, while the other was told to judge the items in terms of their own personal experience. Significant differences were found for items considered critical issues. Gerberich (45) made a study of consistency of responses to questions, using sixty questions, some dealing with fact and others with personal and social adjustment, selected from professional application blanks and attitude and personal adjustment questionnaires. These were interspersed with others in three ostensibly different questionnaires and administered on three successive occasions to 657 college students who were not told that the selected questions were repeated. The consistency of each person for each question was analyzed; for one-day intervals it was 76 percent, for ten-day intervals 74 percent; percent for women slightly higher than for men; and percent for factual questions lower than for attitude-adjustment questions.

### Questionnaire Investigations

The following studies demonstrate types of problems which have been investigated successfully using questionnaires. Baker and Peatman (6), covering a full sample of Veterans Administration advisement units in operation on July 1, 1946, sent the director of each unit a questionnaire asking him to indicate the tests which he found most useful in his unit. This type of investigation, requesting concrete information, and covering a complete sample of qualified respondents represents an optimal use of questionnaire technic.

Cupps and Hayner (28) gave a sample of 182 men and 132 women students at the University of Washington a three-page questionnaire inquiring into their experiences and feelings about dating. Kirkpatrick and Caplow (73) at the University of Minnesota obtained information from students on courtship problems. Brav (19) had fifty women, married from two to twenty-seven years (average twelve and one-half) in a small southern community, fill out a detailed intimate questionnaire giving their views on the honeymoon, based on their own experience. As in these three studies the questionnaire is often a good vehicle for obtaining intimate, personal information, provided respondents are properly motivated to answer frankly, their identity is adequately concealed, preferably by keeping replies anonymous, and the information requested has not been distorted by forgetting.

Wittenborn, Larsen, and Mogil (129) used two questionnaires regarding study habits, one in French and one in Spanish. Each included items relating to personal and emotional reactions, knowledge of subjectmatter, skill, and study technics. They gave these to college students and correlated the responses with objective indexes of academic performance. It was found that a large and useful group of study habits is significantly related to the criteria. Stoughton and Ray (118) had 344 children in Grades II, IV, and VI answer the following questions: "Of all the persons whom you have known, or heard about, or read about, whom would you most like to be like? Why do you like this person?" They used a questionnaire form in the two higher grades. Responses, segregated by grade and sex, were tabulated under three broad categories of persons or characters: (a) those in the child's immediate, everyday environment, (b) those in remote places, including imaginative and fictional, and (c) those in religion. Horrocks and Thompson (55) studied the degree of friendship fluctuation in adolescent friendships in a rural group of 421 boys and 484 girls from ten to seventeen years. On each of two occasions, fourteen days apart, each one was asked to list his or her three best friends. An index of friendship fluctuation was computed and data were analyzed by sex and age. Harris and Watson (52) attempted to answer the question "Are Jewish or Gentile children more clannish?" thru a questionnaire to eighty-two children in grades four to six of an upper-class private school in New York. Each child was required to list his three best friends under three

conditions: (a) choice limited to members of his class, (b) choice limited to children attending the school, and (c) choice limited to children outside of school. Altho the sample was highly restricted, the design of this study is interesting. The results were analyzed directly by comparison of percent of in-group and out-group selections under each category of response. This treatment permitted the conclusion that Gentile children were less likely to choose Jewish friends than were Jewish children to choose Gentile friends.

Pratt (105) and Zeligs (131) studied children's fears and annoyances respectively using the open-question group-response technic. Pratt had a group of rural children from four years to fifteen years ten months, list their current fears, indicating three things feared most and three feared least. Responses were analyzed by grade and sex. Evidence was found of cultural stereotypes, such as fears of lions or tigers. Zeligs had sixth-grade boys and girls of two suburban Cincinnati schools list things which annoyed and irritated them. She then classified the responses into twelve categories, ranging from social relationships to environmental conditions, and incorporated them in a rating scale with response categories from *like* to *hate much*. The following year she presented this rating scale to 285 of the same children and tabulated their response by categories. Clear patterns of sex differences were found.

### Mass Surveys

Mass surveys of large samples of respondents are recognized today as, as well as by, big business. They include market surveys, attitude and opinion polls; they use various types of questionnaires and interviews; and collect data by personal interview, by mail, and by various combinations of these. Some interesting developments were sponsored by government agencies during the war such as a consumer panel, in which a continuous sample of respondents furnished daily information on purchases of rationed foods, to assist the rationing agency in setting point values. Consumer panels are used to study brand preferences, readership interests, or any other specific problems which a sponsor is willing to underwrite.

All these procedures have certain things in common. They secure information from people, using sampling technics, with relatively large numbers of respondents, and attempt to develop generalizations from the samples concerning the whole or a substantial segment of the population. Notwithstanding these similarities, however, there are wide differences in technic of securing information and in sampling required for different problems in this general field. These problems of method have been widely discussed in the literature.

### General Discussions

One of the most comprehensive discussions is McNemar's (90) critical review of opinion-attitude methodology, in which he carefully analyzed

the issues involved in measuring attitudes by scaling technics, in single-question opinion gauging, in the administration of tests, in statistical treatment and sampling, and in conducting morale surveys. Katz (66) wrote a critical comment distinguishing what he called "survey technic" from opinion polling. He holds that the single-question type opinion poll is applicable only on issues where public opinion is crystallized and to which unambiguous questions can be addressed. In such cases, a "cross-section" sample may serve adequately. The "survey technic," on the other hand, is necessary in approaching issues in which public opinion is not crystallized and requires the use of plural devices, subtle and often indirect indexes, more complex sampling and above all careful consideration of scientific method in the analysis of such variables. The "survey technic" was applied by government agencies during the war to the measurement of morale in war industries, and in studying morale as influenced by strategic bombing in Germany and in Japan. Campbell (22), in a companion article, emphasized the limitation of polling to questions that are well understood by the public and are clear-cut. For the remaining questions he recommended "open interviewing," which reveals not only the respondent's yes or no answer, but his interpretation of the question and the intensity of his feeling about it. Bernays (9), addressing himself only to attitude polls and excluding factual and purely quantitative surveys on markets, elections, and similar issues, argued that polls are useful when used as a guide to current opinion, since they cover only a temporary attitude. He was concerned with the prevention of misuse and misinterpretation and recommended licensing sound and ethical polling agencies and educating the people and public leaders in the social significance of polls. Blankenship (13) edited a symposium to which twenty-nine specialists contributed articles dealing with specific aspects of consumer and opinion research and sampling technic as practiced in business, industry, government, and agencies reporting to the public. Ferraby (40) discussed the qualitative and quantitative technics of mass-observation in England.

### Technical Papers

Slight differences in phrasing, order of questions, and like variations, often yield different proportions of favorable and unfavorable responses. Suchman and Guttman (120) described an objective method based on Guttman's technic of scale analysis and intensity analysis of dividing the responses into pros and cons so that the division is not affected by wording or similar variation. The method results in an intensity curve, the lowest point of which will be the same for any sample of questions from the same scale or dimension of opinion. In another paper, Guttman (51) described the technic of scalogram analysis, a method of quantifying qualitative data.

Gallup (43), in reply to criticism of public-opinion measuring, de-

scribed a system of question design which has been evolved out of many years of research by the American Institute of Public Opinion. This method provides an opportunity for probing five aspects of opinion: (a) filter and information questions to find out if the respondent has given any thought or attention to the issue, (b) open or free answer questions to get at unstructured opinions and reveal the direction of the respondent's thinking, (c) dichotomous or specific issue questions in which the public is asked to stand up and be counted on specific issues, (d) questions asking respondents why they hold the opinions they do, and (e) questions to measure the intensity of opinions. It is apparent that most critics have viewed the pollers as practitioners of the dichotomous type of question more or less exclusively.

Campbell (21), in discussing the open-question technic, pointed out that open questions are useful in revealing general attitudes and suggestions about the sources of opinions, but they permit variation in frame of reference and thus allow avoidance of the desired response or make difficult the classification of responses. The questioner must be alert to follow up with added questions to clarify responses.

Connelly (25) pointed out that adequacy of sampling procedures and reliability of results are subordinate to the major problem of validity, which is adversely affected by (a) interpreting a specific response apart from its specific stimulus, (b) failure to write poll questions in terms of the objective behavior in which the poller is interested, (c) believing that the respondents must think clearly (according to the poll author's concept of clear thinking), (d) assuming that the respondents need to know the implications of their opinions to answer validly, and (e) incorporating prestige factors into the complex of questions.

Dodd (32), recognizing the growth of the survey industry, has pointed out the need for, and outlined some forty dimensions of excellence as a basis for standards for surveying agencies. These are divided into six major groups: agency credence standards, questionnaire standards, sampling standards (with some statistical details given), interviewing standards, reporting standards, and administrative standards. These are unquestionably worthy of any research agency.

The questions of administration of field work in large-scale surveys have been discussed by Bevis (10) and by Huey (57). Bevis covered training and supervision of resident interviewers. Huey outlined the special problems and special skills arising in large-scale, organized research. He described the organization and administration of the Morale Division of the U. S. Strategic Bombing Survey in Japan.

Frazen and Lazarsfeld (42) analyzed certain problems in the use of the mail questionnaire. They mailed questionnaires to a sample of 3000 *Time* subscribers, 1000 each of three slightly different forms. Five hundred five respondents and 882 nonrepliers were personally interviewed. The results are stated to indicate that mail questionnaires can produce valid samples of comparatively homogeneous groups and that the answers

to some questions given in a mail questionnaire are more informative and more freely given than the answers the same people give to the same question when face to face with an interviewer. They recognized, however, that significant biases do occur in mail returns, and precautions must be taken to avoid prejudiced generalization.

Guest (50) compared the results of a consumer jury test carried out by magazine votes with one carried out by personal interview. He found that the difference was considerable tho not statistically significant.

### **Illustrative Studies**

The following references illustrate some of the major categories of mass-survey technic, described above, as follows: reader panel: Corson (26); opinion study of a special population segment: Hollis (54), Peterson (103), Faterson and Klopfer (38); information survey: Mills and Atkinson (92), Endicott (37), Kwok (77); attitude survey: Blum (14), Crespi (27), Smith (116), Samuelson (112).

### **Combinations of Observational Techniques**

Several studies have combined several different technics in a manner which justifies special mention. Kitay's (74) investigation of attitude toward religion made extensive use of personal documents, such as autobiographies, essays by students on their attitudes, responses to personal data questionnaires and attitude questionnaires. His study was based on 139 Jewish students of the Commerce Center of the College of the City of New York in 1941 and 1942. Radke (107) investigated parental authority and discipline in the home environment and its correlates in the child's attitudes and social behavior by a number of methods, including questionnaire and interview reports from both parents and children, ratings of personal-social behavior by teachers, and tests, experimental situations, and projective technics on the children. The subjects were forty-three nursery school and kindergarten children, averaging four years eight months in age, from urban homes, representing a select social, economic, and educational sample of the population. Radke found that the projective interviews with the young children yielded valuable data in locating critical areas in the child's home relations and in getting his reactions to known home situations.

### **Observational Instruments and Aids**

#### **Photography**

An outstanding photographic study is that of Gesell (46) which summarizes the physical and social growth of a baby in 800 photographs.

### Eye Movements

Brandt (18) developed a camera which permits simultaneous recording of vertical and lateral eye movements. This is a valuable device for many types of research in reading, attention, illumination fatigue, and related problems.

### Hearing Aids

Davis (30) reported experimental findings and acoustic recommendations on the design objectives of an ideal hearing aid. Gates and Kushner (44) did a research of extreme importance and interest on the factors influencing the decision of children to wear hearing aids. Using tests and extensive interviews they discovered many social and personal factors of controlling importance which can be adopted in the more effective design of hearing aids. Lorge (81) found on audiometer retests after two years of a group of twenty-five hearing aid users and a control group of equal size, that there was no significant difference between aid users and the control group in amount gained in hearing-speech capacity.

### Physiological Measures

Bitterman (11) using continuous electromyographic recordings of cardiac and eyelid activity, obtained while subjects performed visual tasks in two different experiments involving reading material in six- and ten-point type at three and at ninety-one footcandles of illumination, found no evidence that either heart rate or blinking rate is an index of the ease of visual work. Loftus, Gold, and Diethelm (80), in an investigation of electrocardiographic changes accompanying intense emotional states, found evidence which pointed to the possibility of psychogenic origin of the electrocardiographic changes. There was no evidence of cardiovascular disease. Lennox, Gibbs, and Gibbs (79) observed identical electroencephalographic tracings in 85 percent of fifty-five pairs of monozygotic twins. Results of their study indicated that the brain wave pattern is hereditary and that the encephalogram can be used in human genetic studies.

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## CHAPTER VI

### Tests and Measurements

WILLIAM B. SCHRADER and HERBERT S. CONRAD

ACHIEVEMENT testing, broadly conceived, constitutes the basic topic of the present chapter. In preparing this summary, recognition has been given to the fact that certain other issues of the REVIEW cover measurement in specific subjectmatter fields. Some overlap may occasionally be observed within the fields of intelligence, special aptitudes, or personality, in the case of studies having implications for achievement testing.

Persistent attention to long-standing objectives characterized achievement testing during this triennium. Basic conceptions in achievement testing were clarified and extended. Progress toward greater directness of measurement was substantial, tho gains in this direction were generally made at the expense of objectivity or factorial purity. The distinction between the measurement of detailed subjectmatter content and the evaluation of general educational outcomes was sharpened. Numerous large-scale testing programs were energetically conducted.

Promising fields in which too little work was reported included: (a) utilization of research data offered by cumulative records; (b) long-term, follow-up studies of the retention of knowledge and skills during and after the school years; (c) effect of differing motivation and curriculum emphases upon intercorrelations of achievement test scores; and (d) development of improved criteria for validating aptitude and achievement tests. In general, the greatest needs at present relate to test evaluation, test methodology, and the effects of testing upon broad educational objectives.

### Textbooks and Reference Sources

The late C. C. Ross (104) completed a revision of his textbook on educational measurement, taking account of recent contributions in the field, but placing relatively little emphasis on statistical developments. He also prepared a workbook (103) to accompany the revised text. Another workbook was prepared by Remmers and Gage (101), for their measurement text. Adkins *et al.* (1), wrote a practical, generally useful book on achievement test construction, with particular reference to civil service work. The chapter on performance testing should be especially valuable. A new book on guidance technics by Traxler (138) includes an annotated list of widely used achievement tests, along with other valuable material on the use of tests. Crawford and Burnham (25), in their book on forecasting success in college, presented a thoughtful analysis of achievement testing at the college level. Wood and Haefner (154) wrote a book on guidance and testing in a highly popularized style.

In the field of bibliography, Hildreth (68) prepared a supplement to her earlier bibliography on published tests, bringing it up to date as of 1945. Swineford and Holzinger (121, 122, 123) issued their annual annotated bibliography on statistics, theory of test construction, and factor analysis. Finally, mention must be made of the new edition of Buros' important *Mental Measurements Yearbook*, publication of which is likely to fall just beyond the time period covered by the present summary.

### Test Construction

The development of new tests within subjectmatter fields is most appropriately discussed in issues of the REVIEW pertaining to these fields. Notices of newly published tests also appear in *Psychological Abstracts*, the *Journal of Consulting Psychology*, and *Educational and Psychological Measurement* (44, 45). The present summary is concerned primarily with tests developed for research purposes, or those which present some feature of general interest.

#### New Tests

Tests were developed according to logical analyses of subjectmatter fields by Harris (63, 64), Spache (114), and Ebert (43). Harris sought to measure seven logically discriminable aspects of the comprehension of literary materials. He designed an experimental test in which seven reading selections (including poetry and prose) were used, and in which items were systematically constructed to represent the various kinds of tasks. Factor analysis, of the bi-factor type, led him to conclude that a single common factor accounted for the intercorrelations among scores on the seven aspects of behavior. The seven reading selections used also were found to yield only one factor. Spache developed a test of arithmetic reasoning, broken down into five logical aspects, corresponding to five stages in the sequence of solving arithmetic problems. He was thus able to secure five part-scores. The intercorrelations of part-scores were apparently computed for widespread groups, and in consequence are difficult to interpret. Ebert developed a test of generalization abilities in mathematics suitable for eighth-grade students. Three types of performance were required: (a) given several mathematical statements, to write another example of the common principle; (b) given several mathematical statements, to write a verbal statement of the common principle; and (c) given a verbal statement of the common principle, to write a mathematical example. Rather high intercorrelations were found among the various types of items.

Other tests of considerable interest were developed in connection with specific educational research problems. Malter (80, 81) prepared a test of the ability of children to read diagrams involving simple symbols and another test for ability to read cross-sections. These tests were designed to determine whether or not children in Grades IV to VIII could use such aids in printed materials. Reiner (99) constructed a test of cause and effect

suitied to ninth-grade science students. Students were required to state whether a condition in a given sentence was (a) a direct cause, (b) an indirect cause, or (c) no cause of an event in a second sentence. Using a thirty-five minute, seventy-eight item test, he obtained a reliability of .91.

Grener and Raths (59) prepared an interpretation-of-data test suitable for children in the third grade. Horrocks and Troyer (70) developed a case-study test similar to Baller's "Case of Mickey Murphy." The three cases used were carefully constructed to provide adequate coverage of main topics in mental hygiene and adolescent psychology. Items were designed to measure ability in diagnosis and remediation. Troyer (139) described the procedure used in building a more satisfactory master's examination for students of education. The test included a section on the interpretation of professional data and a section which required the student to evaluate the appropriateness of an action or decision in relation to a specific situation. Troyer noted that there was some initial frustration on the part of students when this type of examination was used. Nevertheless, the value of the test for diagnosis and its close integration with objectives were considered desirable features. Angell (6) described the preparation of a test in educational philosophy. Among other things, the test required students to evaluate a series of statements in terms of each of the three schools of thought, and to rank groups of educational issues in order of importance. Robbins (102) used a test in which students were required to evaluate adequacy of reasons for certain opinions. He found that college students performed slightly but significantly better in identifying correct reasons for views with which they agreed than for those with which they disagreed. Bottorf (15) developed a test of art appreciation stressing art in everyday experience. Students were required to express preference for various objects. Evidence for validity of the test as a whole was found in the relationship between mean scores and the amount of art training a student had received. Nahm (90) prepared a situation-response test on mental hygiene for use in a survey of student nurses. She found that about two-thirds had a relatively sound viewpoint, as judged from test performance, but about one-fourth showed a definite lack of understanding.

### Problems in Test Construction

The yearbook of the National Society for the Study of Education on the measurement of understanding (91) made what appears to be an important contribution to testing. For each major field of school achievement, thorough consideration was given to an analysis of objectives and to the presentation of illustrative items dealing with ways of testing or observing the desired pupil behavior. Brownell and Sims discussed eight essential characteristics of understanding and Findley and Scates formulated nine general principles to guide the measurement of understanding. This yearbook represents a very useful source of test ideas for measuring broader objectives in subjectmatter fields. At the college level, the Executive Com-

mittee of the Cooperative Study in General Education (4) provided helpful material for the evaluation of some of the less tangible outcomes of college education.

Engelhart (48) has summarized a series of suggestions to classroom teachers preparing multiple-choice tests for machine scoring. Much of the material is applicable to the improvement of any classroom test. Mosier, Myers, and Price (87) also presented numerous suggestions for improving multiple-choice items, including a list of criteria for checking such items. Diederich (32) described at some length the examination system in use in the University of Chicago's comprehensive examination program. In his judgment, factors which contributed to the satisfactory operation of the system included: (a) emphasis on problem-solving rather than fact questions; (b) the convention that only objectives agreed to by the teaching staff are covered by the examinations; and (c) the fact that students need not take an examination until they are ready. Various other writers who have discussed problems of test construction in specific fields are as follows: Sueltz (119) in arithmetic; Bowers (16) in industrial arts; Beckley (10) in retail selling; Barnett (7) in the social studies; and Meredith and Burr (84) in the area of intergroup education. Hendricks (65) reported on an effort to design paper-and-pencil tests for measuring important objectives in chemistry laboratory instruction. Validation against performance test results was reserved for later study.

## Evaluation

### Validity and Reliability of Tests

For discussion of aspects of reliability and validity which are primarily statistical or computational, reference should be made to the article by Travers (132) in the February 1946 REVIEW, and to chapter VII by Johnson and chapter VIII by Fattu in the present issue. The discussion here is limited to broad problems of validity and reliability, to studies of the validity of specific tests, and to evaluations of test technics in terms of reliability and validity.

*Validity*—In a comprehensive discussion of different kinds of "face validity," Mosier (86) pointed out that "validity by definition" (the test duplicates the criterion) is entirely sound in principle; but that such validity sometimes comes dangerously close, in practice, to "validity by assumption." Rulon (105) urged application of rigid standards to insure duplication between form and content of the test and the desired behavior. Tests so constructed could then be used to validate simpler, more practical instruments.

Dyer (41, 42) studied the validity of College Board placement tests in German and French, using grades in courses at different levels as the criterion. Validity coefficients ranged from .43 to .87 for the German courses, and were in the .80's in the French courses. In a study of the

relationship of scores on a recall-type objective test in German to ratings of translations, assigned by highly experienced instructors, Dyer (40) obtained a validity coefficient of .64 based on 21 students. White (152), in a study of the validity of a test of achievement in high-school English, compared item analysis results on separate parts of the test with known differences in curriculum emphasis between two schools, and found that the differences were in accordance with expectation.

**Reliability**—Two attempts at a general formulation of the interrelationships of various methods of determining reliability appeared. Cronbach (27) evaluated six procedures in terms of the kinds of variances included in the estimate of error-variance used in determining reliability. He concluded that since no method is generally best, test authors should report more than one kind of reliability coefficient. He noted that the estimation of reliability generally involves making assumptions which the experimental conditions probably do not warrant.

R. L. Thorndike (126) made a detailed analysis of sources of variance in performance and evaluated ten possible procedures in determining reliability. His report drew upon the extensive experiences of the Army Air Forces Psychology Program. He stressed the importance, in the case of speeded tests, of obtaining test-retest reliability (by the separate administration of equivalent forms). He also pointed out that the determination of test reliability is sometimes inherently difficult or unsatisfactory; *viz.*, for tests involving insight, tests in which the subject has immediate knowledge of results, and performance tests in which sets of trials are run under conditions which vary appreciably (and generally uncontrollably) from set to set.

### Reliability and Validity of Techniques

Plumlee (96) has compared the relative value of three types of mathematics items at the college-entrance level; *viz.*, "demonstrative," "multiple-choice," and "answer-only." She concluded that the answer-only form was superior to the demonstrative form both in reliability (.92 *vs.* .75) and in predicting course grades (.44 *vs.* .37) for comparable testing time. She found that the multiple-choice and answer-only forms were about equally reliable and equally effective in predicting college marks. The multiple-choice form was, of course, more economical with respect to scoring. Huddleston (71), also working at the college-entrance level, found that an objective test of English grammar, correlated more highly with teacher's ratings on writing ability and with grades earned in English during the two years prior to the testing than did an essay test. Each test was of twenty minutes' duration. The Verbal section of the *Scholastic Aptitude Test* developed by the College Board correlated substantially better with both criteria than did the English tests. Good results from an objective test in predicting English grades were also obtained by Berg, Johnson, and Larsen (12).

Problems related to specific techniques were also attacked in several other studies. Wesman and Bennett (151) did not find any advantage in the use of "none of these" as an alternative in multiple-choice items, altho they found some indications that this alternative tended to slow down response. Using item analysis procedures, Wesman (150) found that it was possible to identify correctly spelled words which have value as regular items (rather than merely as "filler") in a true-false spelling test. Wesman (148) also studied the relative merits of instructions to mark every item "right" or "wrong," as compared with marking only the wrong items, on a test of grammatical structure. No appreciable effect on reliability was found.

### Interpretation of Test Scores

Flanagan (51) predicted that test norms would tend to place increasing emphasis upon socially meaningful statements about performance, along with the numerically expressed relative standings now emphasized. The development of such absolute standards should aid in the interpretation of test results by counselors and administrators. Such an approach implies empirical validation and the determination of critical scores in terms of extra-school standards.

Several articles dealt with technical points in the development of test norms. Thurstone (127) described briefly a procedure which he has long used in making scores on a new edition of a test comparable with scores on an older edition of the test, when the original standardization sample is no longer available. Harris (62) called attention to a common error in the interpretation of grade norms; namely the failure to keep in mind that zero attainment goes with a grade score of 1.0. Stein (115) described a test of homogeneity of variances, which should be used before combining results from different schools when determining local norms. Tucker (140) described a new system of norms for College Board foreign-language achievement tests. These norms were designed to achieve comparability from one foreign language to another, by taking into account the fact that the average amount of students' previous training varied from one language to another. Turnbull (141) found that it was not necessary to take into account the sequence of topics in physics courses in interpreting the performance of students on a college board physics achievement test taken two months before the end of the course.

Closely related to norms is the problem of score profiles. Walker (147) called attention to the need for a means of measuring the difference between two profiles in such a way that analysis of variance could be used to test agreement. Bennett (11) in a brief presentation argued that tests, before being used as separate entries in a profile, should meet a criterion developed by Kelley. Traxler (137) concluded on the basis of intercorrelations of part-scores that vocabulary, grammar, and reading scores on Cooperative Tests of foreign-language achievement are sufficiently different

to justify separate consideration of each. In an experimental study covering two years, Tilton (128) attempted to change the relative position of arithmetic on the achievement test profile. He found that one of six groups studied showed a substantial relative gain; one showed a substantial relative loss.

Relevant to the problem of interpretation of student gains are studies by Woodrow (155) and Wesman (149). Woodrow investigated the intercorrelations of gains on Metropolitan and Stanford Achievement Tests for four elementary-school groups. For three of the groups, gains over a one-year interval were studied; for the other, gains over one-, two-, and three-year intervals. Altho three factors were tentatively identified in the gains, the intercorrelations were characteristically low, indicating that specific variance and error variance were conspicuously present in the gain scores. He also found that, except for one fourth-grade group, the correlations of gains with IQ were characteristically low. Wesman (149) using tenth- and eleventh-grade students, correlated gains in intelligence test scores with gains on achievement tests. The findings are in accord with the view that gain scores, particularly if the lapse of time has been relatively short, tend to yield low correlation coefficients.

A number of reports dealt with factors tending to obscure the interpretation of test performance. Of these, most significant was the review by Cronbach (26), in which he brought together numerous concepts under the general heading of "response sets" (tendency to gamble, speed *vs.* accuracy, and others). Within the field of achievement testing, response sets would presumably be most important in the less structured test situations (including essay tests), in true-false tests, and in tests where the same set of choices may apply to a whole series of items (e.g., true, probably true, uncertain, etc.). Cronbach offered a number of suggestions for minimizing the influence of response sets. Muntyan (89), in a study of retest performance, found that high-school seniors who repeated the same tests after a year did reliably better than a presumably comparable group of seniors taking the tests for the first time. When alternate forms of the test were used in the retest, only the physical science scores were reliably higher for the repeaters. Separate norms were recommended as a means of overcoming the difficulty. Studies of cheating were reported by Krueger (74) and Gross (60).

Relationships between achievement test scores and various other variables were included in several studies. Heston (67) studied the intercorrelations between scores on the *Graduate Record Examination Tests of General Education* and *Cooperative Achievement Test* scores. A factor analysis of the eight scores on the *Graduate Record Examination Tests* revealed a factor tentatively identified as "reading comprehension" with substantial loadings on all eight tests after rotation, and two other factors with relatively small loadings. Morgan (85) found that students with higher academic achievement within their grade were also on the average significantly higher in social acceptance and reputation among children in Grades V

to VIII in a war-boom community. Gough (58) found only a slight positive correlation between socio-economic status and achievement, after IQ had been partialled out, among 127 sixth-grade pupils. Lobaugh (78) found that girls averaged somewhat higher on marks, while boys averaged somewhat higher on achievement tests; insufficient data were presented to evaluate the reliability or relative importance of the differences involved. Schreiber (109), using fifty-three cases, found no reliable gain in arithmetic computation during four years in high school; by contrast, spelling and language usage, literature, and hygiene showed marked gains during this period.

### Evaluation of Techniques for Testing

Vallance (143) undertook a comparison of essay-type and objective-type examinations with respect to their value as learning experiences. Contrary to earlier results in this area, he found that there was no evidence for the superiority of the essay test either as a learning experience or as a means of encouraging students to use a superior learning method in preparing for the test. Diederich (33), in a thoro discussion of the measurement of writing skill, pointed out that the correlation between two three-hour essay examinations written on different topics on the same day did not rise above .55. He argued that higher "reliability" in essay examination grades, if obtained by artificial devices, may lead to loss in validity. Diederich suggested that the efficiency of the essay examination for measurement of skill in writing may be increased by announcing, about a week before the examination, the reading passages upon which the composition will be based. Freeman (54) attacked the monopoly now held by objective tests; and indicated that tests should give more attention to requiring students to express thoughts in their own language. Sims (112) argued for the essay test from another viewpoint, stressing that the essay test gives valuable insights into personal-social development and processes of thought and judgment.

In an exploratory study, Courtney, Bucknam, and Durrell (24) compared written-recall, multiple-choice, and oral-recall coverage of the same material. This problem is worthy of further study, using large samples and varied subjectmatter. Another study which has a definite bearing upon test technic was reported by Davidson and Carroll (29). They found, by use of factor analysis and multiple correlation technics, that scores on time-limit tests of aptitudes frequently represented a mixture of knowledge or skill and speed of performance. Similar investigations are needed in the case of achievement tests.

A number of papers reported useful technics for achievement testing. Tinkelman (129) found that it was possible for judges to rate the relative difficulty of achievement test items in a particular field with satisfactory accuracy, but judgments of absolute difficulty were less useful. His findings imply that items can be arranged in an ascending order of difficulty with a reasonable degree of accuracy on tests which have not been pretested. Herfindahl (66) described two procedures for reading standard scores

directly, using an International Test Scoring Machine. Taylor (125) outlined a number of shortcuts and technics for efficient use of the test scoring machine, and Bice (13) described a procedure for providing detailed knowledge of results to students on machine-scored answer sheets. Traxler (135) advocated overprinting of answer sheets to facilitate hand-scoring and to give students knowledge of their errors. In order to make copying difficult, Lemmon and DuBois (77) developed a procedure whereby students are required to answer questions printed in the same order in the test booklet on different spaces on their answer sheets. Ryans (107) described in detail a procedure for constructing a profile chart, using standard score conversions based on local data. Mosier and Price (88) presented a convenient system for arranging the alternatives of five-choice multiple-choice items in random order.

## Applications

### Planning the Testing Program

Findley (49) outlined a group testing program suitable for a modern school. Among other points related to achievement testing, he recommended: (a) that the tests be given in the fall to guide curriculum planning; (b) that careful cumulative records of results be kept; and (c) that in the first four grades measurement be based mainly on informal tests. Durost (38) outlined a minimum testing program, urging that achievement tests be used at the completion of each major phase of schooling, and that supplementary testing beyond the main program be provided for 10 to 15 percent of pupils. The Spring 1946 issue of *Educational and Psychological Measurement* carried descriptions by various authors of testing programs in a number of schools and colleges.

### Counseling

Bordin and Bixler (14), on the basis of experience with the use of a procedure in which the counselor described the tests and allowed the client to express feelings in connection with the choice of tests, concluded that the technic had promise for increasing the guidance values of tests. They recommend that systematic research be undertaken to provide a more objective and comprehensive evaluation of possible effects. Traxler (134) expressed the view that achievement tests covering broad areas rather than tests in specific subjectmatter fields should be used for most counseling purposes. Diederich (34) described a program of remedial training in English built around the use of comprehensive examinations normally requiring three hours to complete. He reported that good results had been obtained by using recognition tests of writing ability in which students were required to choose among alternative ways of completing passages in actual student themes.

### Teacher Efficiency

A number of pioneering investigations have used pupils' achievement-test gains as an index of teacher efficiency (8, 9, 21, 116). In the best studies, such variables as teacher-load, class size, class homogeneity, and socio-economic status of the groups are kept constant or are allowed for. Gain is measured as the difference between actual and expected gain. The expected gain for a pupil is the average gain for individuals who resemble that pupil in weighted score on a predictive composite; the predictive composite is made up of such elements as mental age, IQ, and scores on achievement tests at the beginning of the term. The statistical analyses utilize class averages rather than individual scores wherever appropriate to save computational labor. Finally, the design recognizes the possibility that a teacher may be more efficient with some kinds of pupils than with others (e.g., upper *vs.* lower halves of a class).

Results from the use of achievement tests in the measurement of teacher efficiency have so far been rather inconclusive, partly because the number of teachers studied has been relatively small. Sometimes the number of teachers in the sample has been little larger than the number of variables employed in the predictive composite. Another weakness is the lack of cross-validation (*i.e.*, the use of a fresh sample, as a check against the capitalization of chance in the determination of regression weights and the multiple correlation coefficient).

It scarcely needs more than mention that achievement tests do not measure all the desirable products of teaching. Consequently, the application of achievement tests in the evaluation of teacher efficiency must be carried out with great caution and discrimination.

### Research

Shannon (110), studying the role of various technics in educational research, found among other things that achievement tests were the most frequently occurring source of data in 1377 research studies published in the *Journal of Educational Research*. Among studies in which use of achievement tests in research produced results of general significance, the following may be briefly noted: Davenport and Remmers (28) found that average score on the Navy V-12 tests (which included aptitude as well as achievement material) for candidates from the various states correlated .63 with average teacher's salary and .80 with current average per pupil cost in the states. Mandell and Adkins (82) found that an interpretation-of-data test, of the type used in the Progressive Education Association Eight-Year Study, correlated well with standing of administrators in the federal government.

The desirability of using achievement tests as criteria for evaluating aptitude measures received some attention. Van Dusen (144) pointed out that the quality of realism obtained by measuring actual performance could not compensate for lack of reliability or fairness to all persons being

measured. Stuit (117) gave two examples of situations in which the substitution of achievement test scores for informal ratings led to important shifts in validity coefficients of predictors.

### Credit by Examination

Interest continued in the possibility of increasing educational efficiency thru the use of achievement tests for granting college credit. Pressey (97) pointed out that the current strain upon educational facilities may be eased by giving credit by examination. A. B. Garrett (56) indicated that sixteen years of experience with credit by examination in freshman chemistry at Ohio State University has led to satisfaction with the results. These tests are given to all students who have high-school credit in chemistry; from 5 to 15 percent are given credit for one-quarter's work in college chemistry. A booklet describing the achievement tests is sent to each student to aid him in reviewing. Programs in other colleges were described by Goetsch (57) and by Wickhem (153).

Tests of the United States Armed Forces Institute have received considerable attention. Detchen (30) provided a summary of information on the USAFI end-of-course tests, subject examinations, and *General Educational Developmental Tests*, including a list of thirty-seven references. Townsend (131) found that the *USAFI American History Test* correlated to the extent of .85 with the *Cooperative American History Test* (based on seventy-five cases); but that the intercorrelations of the parts were too high relative to the reliabilities to justify much use of the part scores.

Studies by Dyer (39), Bradley (17), and Callis and Wrenn (19) support the view that the *USAFI General Educational Development Tests* are excellent as predictors of college achievement. Dyer, Bradley, and Frandsen found low correlations between part scores and amount of college training in corresponding subjectmatter areas implying that these tests fall more nearly in the field of aptitude than of achievement. Frandsen (53) found that the *General Educational Development* natural science test scores correlated with computational and scientific interest as measured by the *Kuder Preference Record*, suggesting that the part scores may reflect interest as well as aptitude.

Dressel (35) presented a summary of how the *General Educational Development Tests* are used in the awarding of high-school diplomas. He noted that aside from mathematics, college courses no longer require fixed prerequisites in terms of high-school subjects. With respect to granting college credit on the basis of *General Educational Development Tests*, he reported a survey conducted by Barrows in which it was found that only about 10 percent of colleges are giving college credit to any extent on the basis of *General Educational Development* performance. Love (79) described the use of the *General Educational Development Test* in the College of Education at Ohio State University. Emphasis was placed on individualizing the use of the tests, with consideration being given to aptitude score before permitting the student to take the examination for credit.

### Armed Services

Chambers (20), studying possible gains for education from armed services training, found that one outcome on which the majority of 258 educators with armed services experiences agreed was the desirability of more frequent use of achievement tests in civilian education. Tyler (142) considered the emphasis on continuous evaluation as one of six factors contributing to the effectiveness of military and naval training programs.

Several books describing armed services programs have devoted considerable attention to achievement testing activities. A general description of the achievement testing program of the Army Air Forces was presented by Flanagan (50). Hobbs (69) reported on a program of measurement using both printed and performance tests of flexible gunnery; in various studies, men were tested at all stages from basic school thru combat. Descriptions of the use of printed and performance tests in the Navy were presented in a volume edited by Stuit (118). The success of the armed services with performance testing suggests that this is a promising field for development. It should be noted, however, that the expense of this type of testing may well present a problem in civilian schools.

### Large-Scale Testing Programs

A significant development in national testing programs was the preliminary report of the Committee on Testing appointed by the President of the Carnegie Foundation for the Advancement of Teaching (22). This committee expressed its belief that the unification of the large nonprofit testing agencies would benefit American education thru the elimination of overlapping effort and thru the availability of greater resources. In December 1947, the Educational Testing Service was incorporated, to bring together the testing activities of the American Council on Education, the College Entrance Examination Board, and the Carnegie Corporation and Foundation (46). The new organization is thus responsible, usually in cooperation with a sponsoring agency, for a number of large-scale national testing programs (47). Among these, achievement tests play a prominent role in: Entrance Examinations of the College Entrance Examination Board; Nation-wide High-School Testing Program; National Freshman Placement Testing Program; National College Sophomore Testing Program; College Chemistry Testing Program; Cooperative Achievement Tests; English Examination for Foreign Students; Engineering Achievement Tests; Graduate Record Examination; National Teacher Examination; and the Preliminary Actuarial Examinations.

Other testing programs of national scope, which place substantial stress on achievement testing are conducted by the Educational Records Bureau; the Project for the Selection of Personnel for Public Accounting (136), associated with the Educational Records Bureau; the Pharmaceutical Survey (100); and the testing program sponsored by the National League of Nursing Education (73). At the elementary level, the program for estab-

lishing norms on the *Metropolitan Achievement Tests*, in which pupils from every state were tested, may well be considered a national program (36).

Anderson (5) has described the Nation-Wide High-School Testing Program in which, during 1946, the *Cooperative Test of Recent Social and Scientific Developments* was given to about 143,000 high-school students in forty-three states. Vaughn (146) discussed the various projects of the Graduate Record Office, including the Inquiry into Postwar Conditions in American Colleges. In this program, forty liberal arts colleges administered to every graduating senior the *Graduate Record Examination Tests of General Education* and an appropriate advanced test in the field of specialization. Vaughn (145) also summarized the development of an achievement testing battery for engineering sophomores. Ryans (107) gave an account of the testing activities of the Committee on Teacher Examinations, and presented descriptive statistics on the 1947 examinations.

Among statewide programs, Smith (113) emphasized the role which testing had played in the activities of the Bureau of Cooperative Research and Field Service at Indiana University. Fox (52) described the rather comprehensive test services offered by Indiana University to schools in the state; detailed information is given on uses of tests, costs, available tests, and norms.

### Current Needs in Measurement

Needs in measurement have been much discussed during this postwar period. A recurrent theme in these discussions is the need for testing to push into new fields, to develop new technics, and to exploit existing technics more thoroly. Adkins (2), Deutsch (31), F. S. Freeman (55), and Wrightstone (156) have suggested specific areas needing active exploration, among the most important of which are critical thinking, originality, and work-study skills. Brownell (18) urged that the appraisal of learning in research studies should stress: (a) the process of performance; (b) the retention of knowledge and skills, especially as measured by the relearning method; and (c) the transferability of learning. In the field of intergroup education, where the need for broadened objectives is perhaps most acute, Raths (98) criticized workers who sacrifice relevance for objectivity, and Taba (124) advocated that very extensive observational study be carried out before undertaking objective test construction.

A need for comparable tests and better norms to permit effective longitudinal studies and more satisfactory individual profiles has been stressed by Durost (37), Wrightstone (156), and Traxler (133). Various writers have expressed a need for a central agency to bring together and expand the stock of available information about tests, and to provide completely impartial advisory service to test users. The need for high standards of scholarship in constructing subjectmatter achievement tests has been indicated by Tolley (130); Palmer (94) and Packard (92) have questioned the scholarship of particular tests. Swenson (120) and Simpson (111) criticized the tendency toward hasty interpretation of standardized test results.

A related problem is one of time and budget. Lass and Wrightstone (75) in a survey of measurement in New York City secondary schools, and Painter and Painter (93) in a survey of forty-four college orientation testing programs, found that lack of adequate time, budget, and clerical help were serious hindrances. Conrad (23), while recognizing that "the individual is ever the source of original ideas," emphasized the need for coordinated institutional resources in the execution of research.

### Trends

A number of writers stressed the importance of measuring general outcomes in terms of knowledge and skills, rather than in terms of time served or detailed course content. Thus, Learned (76) urged that large goals of study measured by suitable examinations replace the present course-credit system; Peik (95) predicted that the general education movement would facilitate such a change. Kaulfers (72) recommended that foreign-language testing be oriented around general goals of achievement of knowledge and skill. The *USAFL General Educational Development Tests* and the *Tests of General Education* developed by the Graduate Record Office may be considered efforts in this direction. Rulon (105) counseled moderation in applying the "generalized outcomes" approach, urging that the content area covered by a test should at least be recognizable. It would appear that the validation of such tests should include a check on the relative contribution of training and aptitude to score variance.

Better understanding of the organization of human aptitudes and abilities should lead to sounder and more efficient testing, as pointed out by Tolley (130). Wrightstone (156) noted a trend toward application of factor analysis to achievement testing problems. Guilford (61), in an article stressing aptitude testing but relevant also to achievement testing, predicted that test authors may presently be expected to report data on the factorial composition of new tests.

In his review of the testing movement from 1897 to 1947, Scates (108) noted that the full significance of the evaluation movement has not yet been realized. He pointed out that while measurement implies "moreness," evaluation implies "appropriateness," and that while measurement seeks simplicity and homogeneity, evaluation recognizes complexity and pays attention to the patterning of data. Megroth and Washburne (83) advocated, as a means of facilitating the measurement of intangibles, the development of a school atmosphere in which the pupil will not be afraid of being judged. Alpern (3) found that New York City academic high schools were using informal records of pupil behavior, along with the more formal cumulative record; several schools were collecting follow-up information about their graduates.

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## CHAPTER VII

### Recent Developments in Statistical Theory

PALMER O. JOHNSON

MUCH of statistical theory and methodology basic to the science of statistics is of recent date, appearing during the past twenty-five or thirty years. Close attention to and appreciation and understanding of the mathematical and logical foundations is necessary for the development of statistics. The basic research under development by the mathematical statistician provides the scientific capital from which fund the practical applications of statistical principles are drawn. There is wide variation among fields and among workers in any given field with respect to the appropriateness and efficiency of the statistical methods of analysis and designs of investigations used. It is hoped that this review may serve to make every research worker more critical of his practices.

#### Books

Two books making outstanding contributions to statistical theory and practice were published in 1946; Cramer's *Mathematical Methods of Statistics* (31) and Kendall's second volume of *The Advanced Theory of Statistics* (69). The former devotes twelve chapters to mathematical introduction comprised mainly of the theory of measure and integration supplemented by other mathematical theorems and tools to make the book mathematically self-contained for a reader with a good working knowledge of differential and integral calculus. The second part of the book contains the general theory of random variables and probability distributions. The main part of the book, entitled *Statistical Inference* is devoted to the theory of sampling distributions, statistical estimation, and tests of significance. The exposition thruout is mathematical in nature but is illustrated by numerous examples from several fields of application. The main emphasis of the theoretical presentation is on the determination of the precise conditions for the validity of the theorems, their connections with general probability and the logical relations among themselves. Kendall's Volume II supplements his earlier Volume I to form together a most comprehensive exposition of the theory of statistics. Four chapters on the theory of estimation, including one on the derivation of the properties of the maximum likelihood estimate, and a chapter each to Fisher's theory of fiducial probability and Neyman's theory of confidence intervals comprise the first section of the second volume. The main section of six chapters is devoted to the theory of statistical tests and treats tests of significance, the analysis of variance, the general theory of testing statistical hypotheses originated by Neyman and Pearson, and recently developed technics of multivariate analysis.

The remaining four chapters are on regression, the design of sampling inquiries, and time series. What the author terms the logical aspects of statistical inference are treated very forcefully in this volume. That is, he presents the broad principles on which inferences are drawn from statistical data in terms of probability. While this book does not attain the mathematical rigor of Cramer's treatment, it contributes both to those readers who are primarily interested in the advancement of research and to the practical statistician who, from its reading, will gain insight into the thinking and acting of the investigator when faced with the problems of planning and interpreting scientific inquiries. The somewhat detailed description of these two books serves to enumerate for the reader the principal problems of statistical science today.

Among other books published during the period, those written by Aitken (1), Hoel (56), Hogben (58), Kelley (68), Thompson (97), Thurstone (99), and the Statistical Research Group (27) may be pointed out for their general or special contribution to statistical theory and practice. A useful index of mathematical tables is now available (45).

### Foundations of Statistical Theory and Method

The development of statistical theory and methodology as an exact science is founded in mathematical probability. The conceptual model constructed to deal with statistical data is grounded on probability theory. The axioms and the structure of theorems based on them make up the subject of mathematical theory. The various ways of choosing axioms have led to different formulations of the theory of probability.

The chief function of statistics in scientific research is in the role of drawing statistical inferences, the process by which new scientific knowledge comes into being. The two problems of statistical inference are: (a) the problem of testing statistical hypotheses and (b) the problem of estimation.

The theory of the design of experiments has as its purpose the development of principles applicable to the collection of primary data in such a way that valid inferences can be drawn from them and for eliciting the greatest amount of information latent in the data in the most efficient way.

Quite the most fundamental problem in practical statistics is the sampling problem. The developments occurring in the design and analysis of experiments have been of special significance in sampling theory and practice.

This delineation of the subjectmatter of statistical science in terms of its major purposes and procedures serves as the basis of classification of the studies reviewed. Some of the studies contribute to several of the areas, but each is placed in that category to which, in the opinion of the reviewer, it contributes most directly.

## Probability Theory

The rapid development of statistics went forward with striking increases in the number and the significance of its diverse applications in many fields. The rapid exploration of new domains left numerous gaps in the theoretical foundations. However, at present and for some time in the past there are increasing numbers of investigations contributing to a more and more rigorous theoretical structure. The firm grounding of statistics in probability theory and the significant contributions in this field are clearly demonstrated in the very comprehensive survey of problems restricted to the purely mathematical aspects of the subject presented by Cramer (32). Modern statistical inference stems from the classical limit theorem of probability. Two fundamental papers dealt with this topic. Feller (39) explained the mathematical content and the meaning of the two most significant limit theorems in the modern theory of probability: (a) the central limit theorem and (b) the law of the iterated logarithm. Erdos and Kac (38) proved four important limit theorems of the theory of probability.

Hsu (60) studied the approximate distribution of ratios of the following two types: (1)  $\frac{Y}{X}$  and (2)  $\frac{Y}{\bar{X}}$ . A knowledge of the probability distributions of ratios has special significance in education and psychology where quotients are frequently used as statistics, for example, the intelligence quotient. It is also important in experimental work to be able to set up the true average of the experimental group as a fraction of the true average of the control group. In this case, what is needed are the fiducial limits of a ratio. The procedure in setting up fiducial limits of a ratio between quantities having normally distributed estimates has been given by R. A. Fisher in his book, *The Design of Experiments* (Fourth Edition).

Other contributions to distribution theory were made by Aroian (6) concerning the probability function of the product of two normally distributed variables, by Hsu (62) on the asymptotic distributions of certain statistics, by Camp (23) on the effect on a distribution function of small changes in the population function, by Chung (24) on the maximum partial sum of independent random variables, and by Bhattacharyya (15) dealing with the distribution of the sum of Chi-squares. Bartlett (9) showed that orthodox probability theory may be extended to include probability numbers outside the conventional range.

## Sampling Theory

While it can be stated broadly that no essentially new methods of selecting representative samples have been developed in recent years, many additions to our knowledge of underlying theory of the various methods of sampling have been made. Furthermore, much development has taken place in technics for estimating the sampling errors of both

simple and complicated sampling designs. Yates (115) published a very comprehensive and informative paper dealing with the developments and applications to problems in area sampling and in economic and social surveys. The intensive use of sampling during the war both in economic and social surveys, and in operational research led to development of methods of sampling for handling materials at times varying greatly from part to part and of methods of estimating sampling errors when sampling units of widely different sizes were used. However, when the discrepancies in size are marked, estimates established on ratios or percents are generally required, which of necessity complicates the estimation of the errors of sampling. Random sampling (without restrictions), stratified sampling (random sampling from groups), subsampling, stratification for two or more factors, and balancing are the principal sampling methods used. All these methods involve random selection of the sampling units and thereby provide exact estimates of sampling error. The analysis of variance, which makes possible the collating of estimates of error and the separation of components of error not strictly homogeneous, has provided the basis for development of the various systematic methods of sampling. The principle of randomization which made possible the development of the various modern designs of experiments correspondingly made possible the development of the relatively complicated schemes of sampling by providing a valid estimate of error in virtue of the random elements in the process of selecting the sample.

A good illustration of the modern theory and practice of sample designs was presented in *A Chapter on Population Sampling* (103). This monograph by the Bureau of the Census Sampling Staff deals mainly with the theory underlying a particular approach to areal sampling with subsampling and demonstrates the use of the "principle of optimum allocation by which the smallest sampling error is obtained for a specified expenditure." Formulas were developed for estimating the total population, the variance of this estimate in terms of population parameter, expectations of the sample variances, and approximations to these expectations. Other illustrations of the problems and methods of sampling surveys were given by Hansen, Hurwitz, and Gurney (54), Hansen and Hauser (53), Jessen (64), and Mahalanobis (75).

Cochran (25), studied the relative accuracy of systematic and stratified random sampling in a type of population in which the variance within a group of elements increases steadily as the size of the group increases. The stratified random sample was found to be always at least as accurate on the average as the random sample with its relative efficiency represented by a monotonic increasing function of sample size. No general result was found valid for the relative efficiency of the systematic sample. Systematic sampling in certain populations of the class of populations specified was more precise than stratified sampling for one sampling rate, but was less accurate than random sampling for a different sampling rate. However, when the correlogram was in addition concave upwards, the systematic

sample was on the average more accurate than the stratified sample irrespective of sample size. Other comparative studies of sampling methods were made by Madow (74) and by Brown (22).

Gumbel (49) studied the conditions of independence of the extremes in a sample. Thurstone (98) considered the theory of univariate and multivariate selection in factor analysis, making a comparison of the psychological interpretations of the resulting factors. Baer (7) contributed to the problem of sampling from a changing population. Cases arise where it is not possible to take more than one sample at any given time and if the population changes between successive samples, the problem arises of estimating from a random sampling of the original population certain parameters of a family of populations. The stochastic limits for the mean, variance, and certain other statistics of the sample were determined. Molina (78) presented a method of analysis and presentation for use in estimating a population fraction from a sample fraction, which utilizes both statistical data and collateral information.

To the great fundamental advances in the theory and technics of sampling, most workers in educational and psychological research seem to remain completely indifferent. Only two publications bearing on sampling problems in these fields were located. Cornell (29) applied the method of stratified sampling to a survey of higher education enrolment for the purpose of securing an unbiased estimate of the total enrolments of various types of students in six major classes of higher educational institutions. Marks (77) pointed out that it was difficult to find any study in psychological research that used sampling designs which made possible the valid estimate of sampling error. He used the description of the sampling methods in the revision of the Stanford-Binet Scale to illustrate how the design could not yield statistics with measurable standard errors. Marks also treated the technical problem of cluster sampling in psychological research showing how cluster sampling almost always increases sampling error as compared with unrestricted sampling error of the same number of cases. This is attributable to the practice of sampling previously existing groups of the population which involves a positive intraclass correlation of the variable under investigation. Since cluster sampling is an extremely valuable method of sampling in psychological research it is essential to know the conditions and means by which statistical estimates and the measures of their sampling error may be accurately made.

The need is urgent for thorough studies of the efficiency of different sampling procedures for the different types of problems in educational research.

### Test of Statistical Hypotheses

Suppose that a random variable  $X$  is the measurement of a certain character and that a number of repeated measurements are carried out, say  $N$  times. We then secure  $N$  random variables:  $X_1, X_2, \dots, X_N$ . It is

assumed that the  $N$  random variables are independently distributed and the set of values comprises a sample of  $N$  independent observations on  $X$ . Assume that the probability distribution of  $X$  is normal but that the values of some parameters,  $\Theta_1, \dots, \Theta_q$  specifying the population are unknown. Any assumption about the unknown parameters,  $\Theta_1, \dots, \Theta_q$  may be called a statistical hypothesis. Situations are often met in research in which hypotheses are advanced regarding the properties of the probability distributions of certain variables and we wish to test whether available statistical data are compatible with the hypotheses or not. A test of this general character is called a test of significance relative to the hypothesis under consideration. The hypothesis that chance factors may have given rise to an observed effect is frequently called the null hypothesis, an hypothesis which is encountered in a number of different forms in research or statistical work. As mentioned earlier the testing of statistical hypotheses is one of the fundamental problems of statistical inference. The studies dealing with this problem are presented in five categories.

*General theory of testing statistical hypotheses*—Fisher (43) discussed the process of reasoning involved in using observations as a basis for making probability statements about parameters, the knowledge about which is derived only from such observations. In contrast to his interpretation of statistical tests there is the interpretation built on the frequency concept that the level of significance in significance tests is equal to the frequency with which the hypothesis under test is rejected in repeated sampling of any fixed population permissible by hypothesis. The latter interpretation is basic in the Neyman and Pearson approach in dealing with tests of statistical hypotheses. Pearson (83) presented as an illustration of this interpretation the problem of testing the significance of a difference between two proportions in a 2 X 2 table. There may be two possible outcomes of a test of an hypothesis,  $H_0$ ; either the hypothesis is rejected or it is accepted. Since there are two different actions with respect to testing  $H_0$ , there are two different kinds of errors of judgment: (a) errors of the first kind consist in an unjust rejection of  $H_0$ , and (b) errors of the second kind consisting in the failure to reject  $H_0$  when, in fact, it is incorrect; that is, when some alternative hypothesis is true. To know the properties of a statistical test is to know the probabilities of the two kinds of error that may be committed in the application of the test. The property of the test associated with the control of the second type of error is designated as the power of the test. The power function is also of great value in comparing the relative merits of alternative tests of the same hypothesis. Hsu (61) dealt with the power function of the  $E^2$ -test and the  $T^2$ -test. Johnson and Hoyt (65) extended the utility of the Johnson-Neyman concept of the "region of significance" by formulating the theoretical basis and illustrating useful results for a three-dimensional region. Welch (108) generalized "student's" problems to include the case of testing the significance of the difference of means of populations with unequal variances. Wilks (112) developed test criteria by the Neyman-Pearson method of likelihood ratios for testing

simultaneously the equality of means, equality of variances, and equality of covariances in a normal multivariate population of  $K$  variables on the basis of a sample. An application of these criteria was made in testing the hypothesis that three "parallel forms" of a test are really parallel forms as far as means, variances, and covariances are the same. Grant (47) illustrated the use of certain statistical tests, including the criteria of randomness, in learning and problem solutions in experiments in psychology. Johnson and Tsao (66) developed a test of the homogeneity of a set of variances when correlation exists between the means and standard deviations. This test is of special value in analyzing the effect of increasing age on variability of traits. David (35) developed a Chi-square, smooth test for goodness of fit which takes into account the sign of the deviations of observations from hypothesis and the order of these signs.

Other studies treated the test of significance for intraclass correlation when family sizes are unequal (14), the use of the range in the t-test (73), the use of ranking methods in testing the significance of differences in individual comparisons (111), operating characteristics (40), the use of the statistical sign test based on the differences between pairs of observations, with a table of significance levels (36), the principle of likelihood for testing a broad class of statistical hypotheses (59), the significance of trend differences (73), and the effect of intraclass correlation on certain significance tests (107). Useful tables have been prepared which provide the means of making the most efficient test now available for testing the homogeneity of a set of estimated variances (96).

*Sequential tests*—An important extension of the Neyman and Pearson ideas on testing hypotheses was evolved by Wald (106) and his associates (27). The method of sequential tests of a statistical hypothesis applied, as yet, principally to the analysis of industrial products consists in the application of a sequential probability ratio to the observations taken one at a time. After each observation one of the following actions is taken: (a) the lot or process under examination, or the statistical hypothesis under test, is accepted, (b) it is rejected, (c) judgment is suspended and another observation is taken. In cases (a) and (b) no further observation is taken. The claim made for this test, where it is applicable, as against the classical tests, which use a sample number fixed in advance of the experiment, is that it can satisfy the conditions of the test with a smaller average sample size often as much as 50 percent less. Sequential procedures are based upon conditions of randomization or where the sequence of the results upon inspecting the items is a random sequence. The actual procedures in conducting the experiment determine the test to be used. It is worthy of note that in this process the role of statistical analysis is in the very process of experimentation itself as compared with its consideration at the time of designing the experiment, characteristic of modern experimental designs.

A special case of sequential analysis was treated by Stein (94), who developed a two-sample test of a linear hypothesis, the power of which is

independent of the variance. Cowden (30) provided an illustration of the application of sequential sampling in testing the achievement of students in a class in statistics.

*Rank correlation*—Since rank correlation is a useful technic for the analysis of certain kinds of data arising in educational research, investigations of this technic are of importance to educational research workers. An increasing amount of attention is being given to problems of statistical inference which are referred to as nonparameter problems; that is, problems in which the cumulative distribution function of the population may be held to be continuous but in which the function is arbitrary within a broad class. In these problems, ordered statistics (ranked sets of values in a random sample from lowest to highest values) come into prominent use. The rank-correlation coefficient is an example of a nonparametric test for two dimensions, based on the method of randomization.

Daniels and Kendall (34) considered the problem of setting up confidence intervals for a rank-correlation coefficient in a correlated population and developed a test of significance for the difference between two rank-correlation coefficients. Hoeffding (57) showed that the sampling distribution of Kendall's (1938) measure of rank correlation,  $\tau$ , tends to normality as  $n \rightarrow \infty$  for any population with continuously distributed X and Y if a certain condition holds. Sillitto (92) treated the problem of the probability distribution of Kendall's  $\tau$  for cases in which ties occur in one of the two rankings. He also constructed a table for use in showing the probability of attaining or exceeding an observed score value ( $S$ ) by chance where paired or triplet ties occur. Whitefield (110) built upon the results of Kendall (70) in treating the case of tied rankings to the determination of the relation between two variables one expressed as a ranking and the other as a dichotomy. This problem is often encountered in determining the relationship of a psychological measurement and an external criterion.

*Analysis of variance and covariance*—The analysis of variance technic developed by R. A. Fisher twenty-five years ago in connection with certain experimental designs in agriculture is the principal research tool of the biologist and is being increasingly used in the physical sciences, in engineering, and in the social sciences. Apparently its great powers are just beginning to be exploited. The principal purposes of the analysis of variance are: (a) to obtain efficient estimates of certain treatment differences of interest to the experimenter, (b) to obtain a measure of the degree of confidence to be placed in the obtained estimates by means of estimated standard errors, fiducial limits, or confidence intervals, (c) to carry out tests of significance that are valid and sensitive. For the intelligent and efficient use of any statistical tool the research worker needs to know the assumptions underlying their proper use and how to test them. The conditions have not often been made clear in the textbooks or manuals, and it is not often that reports of researches employing analysis of variance procedures have provided any evidence as to whether or not their use was justified in the particular situation. Three useful papers, recently published,

have dealt with the conditions underlying the efficient use of the analysis of variance technic. Eisenhart (37) enumerated the several assumptions underlying the analysis of variance and treated the practical importance of each. Cochran (26) pointed out the consequences when certain assumptions are not satisfied and gave important information on means of detecting the failure of the assumptions as well as on how to avoid the more serious consequences. Bartlett (10) treated the problem of transforming the original data by changing the scale of measurement in order to make statistical analysis more valid. He gave particular consideration to the use of transformations, such as the square root, the logarithmic, and the inverse sine transformation in applications of analysis of variance. Another important paper by Bartlett and Kendall (11) dealt with the logarithmic transformation in analyzing heterogeneous variances. Irwin (63) treated the problem of interpreting the within and between class analysis of variance when the intraclass correlation is negative.

The use of the analysis of variance would be greatly limited, particularly in education and in the social sciences generally, if, as was the original case, equal or proportionate numbers of observations were required in the subclasses. Several important recent papers have dealt with the problem of unequal representation. Tsao (101) provided a mathematical solution for the general problem of the analysis of variance and covariance where there is unequal representation in the subclasses. He also presented certain approximate methods of practical use to research workers. Other contributions to this problem were made by Ansbacher and Mather (5), by Baten (12), by Hazel (55), by Patterson (82), and Tsao and Johnson (102).

Fisher (44) gave a simple solution by the analysis of covariance method to the often puzzling problem of the relation between a part and the whole. Finney (41) showed how the precision of mean comparisons can often be increased by the application of analysis of covariance.

*Multivariate analysis*—Modern multivariate statistical theory has given rise to new exact tests of statistical hypotheses in terms of probability, which may involve extensive multiple measurements. In 1936 Fisher introduced the discriminant function by which can be solved the problem of specifying an individual as a member of one of many populations or the classification of a number of populations based on the configuration of various characteristics. Mahalanobis' generalized distance function,  $D^2$ , can be used to measure the "distance" between sets of multiple measurements, for instance, to determine whether any two members of a constellation are closer to one another than any two belonging to different constellations. Hotelling's generalized "Student's Ratio" is a powerful tool for the discrimination of mean values between multivariate normal populations (on the hypothesis of equal variances and equal covariances). Contributions to the theoretical or practical solution of problems in this area were made by Von Mises (105), Radhakrishna (89), Bose (19), Yardi (114), and Beall (13).

The noncentral Wishart distribution is the joint distribution of the sum of squares and crossproducts of the deviations from the sample means when the observational values originate from a set of normal multivariate populations with stable covariance matrix but with expected values varying from observation to observation. This distribution is the basis of obtaining the power function for many statistical tests in multivariate normal statistics. Anderson (4) applied the noncentral distribution to obtain the moments of the generalized variance and the moments of the criterion for linear hypotheses when the population means lie on a line or a plane. Guttman (50) evolved a new approach to paired comparison and rank order.

Other theoretical or applied problems involving multivariate analysis were presented by Jones (67), Tintner (100), Wherry and Taylor (109), Bittner (17), and Brogden (21).

### Theory of Statistical Estimation

The problem of estimation is one of the cornerstones of statistical theory. The theory of statistical estimation treats the problem of estimating values (statistics) of the unknown parameters of distribution functions of specified mathematical form from random samples assumed to have been taken from such populations. The most important general method of estimation is the method of maximum likelihood. Interval estimation is given either by fiducial limits or confidence intervals. Halmos (52) discussed a necessary and sufficient condition for the existence of an unbiased estimate and illustrated by application to the moments of a distribution. Bhattacharyya (16) attempted to find a lower bound of variances of estimates of a given function of the parameters which is independent of the estimates used. Vatnsdal (104) found the position of the point about which the variance of the second and of the third moments is a minimum. Smith (93) contributed to the theory of estimating linear functions of cell proportions. Pillai (84) studied different methods of setting up the confidence limits for the correlation coefficient. Girshick, Mosteller, and Savage (46) presented some theorems with applications dealing with unbiased estimation of the parameter  $P$  (fraction defective) for samples drawn from a binomial distribution. Two studies (8, 48) dealt with relations between range and standard deviation. Aiken (2) derived linear approximations by least squares making use of the properties of the variance matrix. Winsor (113) developed a general principle that when possible the experiment should be designed so that the desired regression function can be determined directly; where this is not possible the inverted regression should be used.

Mosteller (80) proposed a number of statistical technics for the economical analysis of large masses of data by means of punched-card equipment. The principal technic is the use of functions of order statistics which promises to provide a simple and effective practical method for estimating parameters of normal and other populations which have a continuous cumu-

lative distribution function. Scheffe and Tukey (91) validated the existing solutions in the nonparametric case for setting up confidence intervals for an unknown quantile and population tolerance limits. The assumption involved only a continuous cumulative distribution function.

The analysis of variance technic has been used chiefly in making tests of significance. Another significant use, not very well known, is in dealing with problems of estimation, that is, in the detection and estimation of components of random variation associated with a composite population (37). In problems of this kind the parameters involved are variances, the absolute and relative magnitudes of which are of chief importance. Crump (33) has treated very thoroly the problems involved in this use of the analysis of variance technic. Satterthwaite (90) developed an approximate distribution of the estimate of variance components, based on the Chi-square distribution.

Stevens (95) discussed scales of measurement with special consideration to psychological measurement under three phases: (a) the various rules for the assignment of number, (b) the mathematical properties (or group structure) of the resulting scales, and (c) the statistical operations appropriate to measurements performed with each scale type. Cornell (28) discussed the characteristics of the major types of apportionment formulas. Mann (76) treated a problem of estimation occurring in public-opinion polls. He showed that the variance of the estimate in public-opinion polls is somewhat larger than the variance in random sampling because a cluster and not a random sample is used.

### Design and Analysis of Statistical Investigations

The principles of the design of experiments were laid down by R. A. Fisher, and by 1926 the essentials of good experimental design and analysis were determined: replication, randomization, and control of variability. The analysis of variance technic was a simultaneous development. This technic supplies the appropriate method of estimating the experimental error and of carrying out the exact tests of significance. It is a commonly accepted statistical principle that the valid interpretation of a body of data requires a knowledge of how the data were obtained. Equally it is understood by the modern research worker that the conclusions drawn from experimental results must be based on a knowledge of experimental principles at all stages of an experiment. The most efficient method of analysis can be employed and the greatest precision secured only if the experiment is planned with this end in view. The principles laid down by Fisher have stood the test of time and are being used successfully in most experimental sciences. There has been some change in emphasis during the last two decades away from a tendency to overemphasize the importance of tests of significance to more emphasis on the estimates of the effects of treatments and the measurement of their experimental errors. There have been new types of design developed many of which are connected with

factorial design, which design includes all combinations of a set of factors in the same experiment.

In spite of these developments the prototype of educational experiments is the single factor experiment presumably based on the doctrinaire theory that an experiment must be simple and apply the so-called "law of the single variable." The modern principles of experimental design would be of special importance in large-scale cooperative experiments so much needed in education. The importance of planning is clearly indicated in the case of experiments or other observational programs, such as longitudinal studies running over periods of years. Major changes in such investigations are usually impossible after they are underway and serious mistakes in designs would necessitate the scrapping of the whole investigation.

Space permits only a few studies dealing with experimental design and analysis to be reported. Nandi (81) considered the problem of estimating linear functions of unknown parameters and testing various hypotheses relating to them. He gave the analysis of variance of Split-Plot and Strip-Arrangement Designs showing that the estimates of experimental errors were different according to the hypotheses tested about different sets of parameters. Bose (20) formulated methods of attacking the problems of balancing and partial confounding and illustrated the actual working out of these processes. He also generalized certain recent results of Fisher with respect to the maximum number of factors that can be accommodated in a symmetrical factorial experiment subject to the conditions that no main effect or two factor interaction is confounded. Kishen (71) provided a comprehensive general solution for the design of experiments for weighing and making other types of measurements. Plackett and Burman (86) worked out the designs for optimum multifactorial experiments in physical or industrial research. Plackett (85) educed certain generalizations in multifactorial designs. Anderson (3) reviewed the various contributions that have been made to the problem of missing-plot techniques and derived some formulas for missing plots in split-plot experiments by minimizing the error variance. There is considerable need in educational research for developing techniques for handling the many situations, which arise where data are incomplete for certain experimental subjects. Haldane (51) presented certain simple designs based on logical rather than experimental principles for the study of the interaction of nature and nurture which is one of the main problems in genetics.

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## CHAPTER VIII

### Computational Techniques

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THE flood of computational demands brought on by the war quickly swamped available equipment and computers and lent considerable impetus to the development of more rapid computational devices. War-time restrictions kept information about these devices out of circulation until recently, but in 1947 a host of articles began appearing in engineering and applied science journals, and in October 1947 the journal *Mathematical Tables and Other Aids to Computation* began a new indexing section, "Automatic Computing Machinery."

Material published during the past three years on computational techniques may be classified in terms of its relation to: high-speed automatic computers, mechanical computers, tabular and graphical devices and variations in formulas and technics. Most of these devices and changes, except the automatic computers, are familiar to educational research workers.

#### General Bibliographies

Besides the indexes available in educational and psychological journals, bibliographies and summaries may be found in Clark (27); George (55); Murray (108); the Fletcher, Miller, and Rosenhead index (51); and the Harvard Computation Laboratory Manual (75); in the *Journal of the American Statistical Association*, "Statistical Methodology Index" (22); the *British Journal of Psychology*, "Statistical Section"; *Mathematical Reviews*; *Mathematical Tables and Other Aids to Computation*; and the International Business Machines Corporation *Bibliography* (81).

#### High-Speed Automatic Computers

New mechanical and electronic computers, developed since 1942 largely under the pressure of the war, handle information with great speed and skill no matter how long the routine may be. Two differences may be observed between these machines and conventional equipment: (a) data and the entire routine for solving a problem are put into the device and it automatically carries out the operations printing the answers as it obtains them, (b) information can be transferred automatically from any part of the machine to any other part. For example, the machine can be fed tables required for certain sequences in the calculation, and at the proper times the device will almost instantly refer to the required entry and use it in solving the problem. General discussions of these machines were published by Alt (2, 4), Archibald (6), Berkeley (13), Burks, Goldstine, and Von Neumann (21), Comrie (29), Duncan (41), Hartree (66, 68, 69), Peterson and Concordia (112), and Stibitz (121, 122).

At least five types of automatic computers were in operation during the war: the Bush Differential Analyzer, the Electronic Numerical Integrator and Computer (ENIAC), the IBM Automatic Sequence Controlled Calculator, the Bell Telephone Laboratories Relay Computer, and the Electronic Discrete Variable Computer (EDVAC).

The Differential Analyzer (5, 13, 23, 67, 112) produced under the direction of Vannevar Bush handles with uncanny accuracy addition, subtraction, multiplication, division, integration, and the like as continuous operations by means of eighteen integrating devices and 130 mechanically coupled rotating shafts. Initial values and instructions are fed into the machine as punched holes on a paper tape, and answers come out typed by electric typewriters and/or as graphs. It performs integrations directly, works differential equations which cannot be solved by direct means, and gives numerical answers rapidly to five-decimal place accuracy.

The Sequence Controlled Calculator (1, 13, 66, 67) was constructed thru the cooperative efforts of IBM engineers and Professor Aiken of Harvard. A series of ten-position relays, similar to counter wheels, handle the digits zero to nine. The counter positions are connected in banks of twenty-four so that numbers of twenty-three digits can be handled. Numbers go into the machine by feeding punched cards, setting hand switches, or as tables punched on long paper tapes. Instructions are put in as a long sequence of rows of punched holes on an endless paper tape called the sequence control tape. Results come out punched on cards or typed by electric typewriters. The Harvard Computation Laboratory *Manual* (75) gives instructions for coding data for the machine.

The ENIAC (4, 13, 56, 66, 68, 109) represents digits by pairs of rows of ten vacuum tubes each. In one row of the pair a tube corresponding to the digit recorded is turned on. In the other row all the tubes are turned on except the one corresponding to the recorded digit. To add unity a single impulse is sent thru which extinguishes the lighted tube in the first row and lights the next tube. Other numbers are added by sending impulses thru repeatedly. Impulses may be sent at the rate of 100,000 per second. The numbers handled are of ten-decimal places. Additions are made at 5000 per second, and multiplications at 350 per second. Numbers go in by direct setting of switches or by feeding cards. Results come out punched on cards. Instructions are put in by plugging in and connecting tubes—a slow and tedious process. Once plugged in the ENIAC works so fast that it can compute the trajectory of a projectile faster than the shell itself can travel thru the air (13).

In the Bell Telephone Laboratories Relay Calculator (2, 13, 21, 121, 122) two-position relays are used to represent numbers. Five open and two closed relays represent each digit. Decimal numbers are put into the machine in binary form. The machine is extremely flexible and dependable, and complicated routines are readily handled. Besides handling the four fundamental processes, it can consult any of six tables of 1000 numbers

each; it can remember thirty numbers of seven digits each and their decimal points; it can refer to any of twenty-five routines; it can record results on paper tape and later in the same problem use them in further calculations. Altho this is the slowest of the machines discussed, it is estimated that a single machine can do the work of about 100 human computers.

In order to combine the flexibility and accuracy of the Bell Relay Computer and the speed of the ENIAC, the EDVAC was developed (4). Only sketchy information has been published up to this time on the EDVAC.

Womersley (142) and Berkeley (13) have emphasized that in order to make efficient use of these machines a new type of thinking is needed. Formulas and procedures selected for the ease with which they could be applied to pencil-paper computing are no longer adequate. Suggestions of such changes appear in the Harvard *Manual* (75). An interesting development in this connection is the use of "flow diagrams" described by Goldstine and Von Neumann (57). These "flow diagrams" emphasize the logical aspects of the problem and subordinate the purely arithmetical. After completion of a "flow diagram," the actual coding is fairly easy, tho tedious.

Comrie (30) and Hartley (64) have recognized that these machines are extraordinary devices, but have also observed that their cost and complicated routine of coding data and instructions make them useful only for problems involving huge masses of data and intricate routines of computation. For most practical purposes the burden of computation must be carried by conventional mechanical devices as it was during the war.

### Mechanical Computers

Punched card equipment, mechanical accounting machines, and the various kinds of desk calculators comprise the mechanical calculators. Bibliographies may be found in Murray (108), George (55), and in the International Business Machines Corporation *Bibliography* (81).

Most of the applications reported in the literature surveyed were concerned with punched card equipment. Especially prominent was the large number of applications in engineering and applied sciences probably forced upon workers in these areas by wartime demands. Herget (72) used a tabulator and multiplying punch to describe the equation of motion of an  $n$ -body problem. Bergman (11, 12) used punched card equipment to solve differential equations; Munk (107), Leppert (96), Kormes and Kormes (89) indicated aeronautical applications; Cox, Gross, and Jeffrey (33) illustrated applications in crystallographic analysis; Eckert (45) and Frear (52) described applications in chemistry.

The printing of mathematical tables was further discussed by Eckert and Haupt (46). Laderman and Abramovitz (93) described the use of tabulating equipment in differencing tables, and then pointed out that in the U. S. Hydrographic Office Mathematical Tables Project the Sunstrand

Accounting Machine, Model D, was used. It efficiently checked the accuracy of tables by differencing and it also could reverse the operation to construct tables from differences. Reynolds (114) used a prepunched master deck in constructing tables which involved extracting numerous square roots.

Grosch (60) described a method of harmonic analysis by use of progressive digitizing. Alt (3) delineated the method developed at the Aberdeen Ballistic Research Laboratory for multiplying matrices by using punched cards. He also described the set-up for finding the inverse of a matrix by successive approximations. Kimball (87, 88) listed some punched card computational methods used by the Census Bureau, and Kempthorne (85, 86) indicated the uses of a punched card system for survey data.

Advantages and disadvantages of multiple punching were summarized by Benjamin (10) who also suggested efficient means of coding and wiring to extract information. Taylor (127) described the use of an alphabetic punch in conjunction with coded step intervals to increase the amount of data punched on a card. He suggested the resolution of two difficulties, (a) separating the zone from the numerical punches, and (b) distinguishing between the *X* and the *Y* punch in tabulating. Bartlett (9) reported a process for listing scattergrams.

Ellis and Riopelle (47) used a sorter, alphabetic tabulator, a collator with a card counting device, and a summary gang punch to compute higher moments as well as sums, sums of square, and crossproducts. Dwyer (42) reported formulas and procedure for correlation coefficient summation when there were missing variates. To eliminate information in other fields corresponding to the missing variate, the method used was an elimination field and *X* distributors when the missing information was punched *X*, or digit selectors when the missing information was not punched.

Tucker (134) described in detail a simplified punched card method in factor analysis which required only a limited amount of equipment, i.e., a key punch, an alphabetic accounting machine with either complete progressive totals or a summary punch, and counters that both add and subtract. An illustrative example was worked out, including complete operating instructions and machine set-up. The iterative trial procedure rather than the sign change method was used.

Mosier (105) described the use of IBM accounting equipment in carrying out an iterative procedure for arriving at weights for a set of questionnaire responses. The problem involved scaling 100 items on a housing inventory so that weights assigned would yield the most reliable over-all index. Weights were assigned arbitrarily and then adjusted by successive iterations. Three iterations were sufficient in the example reported. Kurtz (92) used data from life insurance agents' rating charts punched on IBM cards to determine how to score the various items of information to yield the maximum correlation with sales and persistence. Other useful applications of punch card equipment are reported by Cochran (28), McQuitty (101), Dyer (44), and Homeyer, Clem, and Federer (74).

Berkeley (13) indicated how written information might be put into punch card form, and Gull (61) illustrated a punched card system for bibliography and indexing of chemical literature. Black and Olds (17) described how detailed tables of census data might be made available to users at a minimum cost.

The use of punched cards was also discussed by the International Business Machines Corporation publications (77, 78, 79, 80).

Calculations made directly from test scoring machines were discussed by Froehlich and Keller (53) and by Herfindahl (71). Epstein (48) reported on statistical analysis with hand punched and sorted cards. While these are interesting applications, the use of punched cards in handling the same problems seems to be more efficient and far more flexible.

Various kinds of mechanical calculating machines were also discussed. The construction of calculating machines was comprehensively treated by Murray (108). He considered digital machines and the component parts of desk calculators, continuous operators, composite analogue devices such as differential analyzers, network analyzers, linear equation solvers, and mathematical instruments such as planimeters, harmonic analyzers, and the like. The book, however, contained nothing on large-scale discrete variable calculators. Berry and Pemberton (15) described a twelve-equation computing instrument, Bleik (18) reported on a machine for solving quadratic and cubic equations, and Zuse (146) designed a rapid but in several respects impractical computer.

Sadler (115) and Comrie (30) expressed the belief that full exploitation of the capabilities of the commercial calculating machines was usually the most efficient way of dealing with ordinary problems. The coupling of two or more machines together, with automatic transfer of results from one to the other, produces a considerable increase of efficiency. Comrie discounted the customary value assigned to electric over-hand operated machines since coupling and transfer could be adapted more readily to the hand machines.

### Tables

In a thoro and painstaking manner Fletcher, Miller, and Rosenhead (51) summarized the mathematical tables published before 1944. Part I of the book consists of an index of tables arranged according to function tabulated. Under each table listed there is noted the number of decimals and figures, the interval and range of the argument, the facilities for interpolation, and the authorship and date. Known corrections, if brief, are then listed, otherwise reference is made to the bibliography of Part II, where sources containing the detailed corrections may be located. Tables which met the authors' unspecified standards of excellence are listed in bold type. Several tables of the normal probability integral, the *t* and the *F* distributions are so listed, but no table of Chi-square appears in bold type. Part II contains a bibliography of some 2000 items, which refer to the

tables indexed in Part I, and to books on probability and statistics including applications to education and psychology. Tables developed since 1944 are summarized in *Mathematical Tables and Other Aids to Computation*.

In the literature reviewed there appeared a number of tables of interest to computers in educational research. For interpreting tests of significance several tables may be referred to. The extension of the *F* distribution table by Merrington and Thompson (103) gives entries to five-decimal places and probability levels extending from 0.005 to 0.50. With reference to the *t* distribution, Baldwin (8) observed that the use of normal deviates when the degrees of freedom exceeded thirty gave results smaller than the true values. To provide accurate *t* values she extended the table to 100 degrees of freedom. Thompson and Merrington (130) reported tables for testing the homogeneity of a set of variances which are better approximations than the values based on Bartlett's test. They discussed a common misconception, namely that if the probability of heterogeneity is less than 0.05 or 0.01, the sample variances are treated as tho they were estimates of a common variance. In their judgment this procedure is likely to lead to errors of the second kind in certain instances, but these instances are not specified because that problem has not been investigated mathematically. Pearson and Hartley (111) presented tables for finding the probability that the range of sample A exceeds that of B by a certain ratio, and for finding the limits of the range corresponding to prescribed probability levels. Hartley (65) similarly considered the use of the mean deviation and tabulated its integral. Baker (7) studied the distribution of the ratio of sample range to standard deviation for normal and combinations of normal distributions. Tables were presented for making tests of significance. A simple test of significance based upon signs of differences between pairs of observations was devised by Dixon and Mood (38). Illustrative examples and a table of significance levels were included. This appears to be a useful device for quick appraisals but the efficiency is probably low. Festinger (49) converted scores to rank order and then tested significance between means without reference to frequency distributions. Tables of the 0.05 and 0.01 levels were given. He argued that what the test lost in precision by conversion to rank order was compensated for by the gain in generality since the test could then be used with any distribution. Wilcoxon (141) discussed individual comparisons by ranking methods. Grant (59) considered some of the recent work on probability of "runs" and developed a table and a criterion for testing the significance of responses in learning and problem-solving. Taylor (128) reported tables for determining the significance of skewness and of differences in skewness when expressed in terms of Fisher's *g* statistics.

Other tables of specialized application are those by Swineford (123, 124), Jurgensen (84), Taylor and Gaylord (129), Lichte (99), Davis (37), Lehmer (95), Croxton and Cowden (35), and Leverett (97).

Carter (25, 26) contrasted the effectiveness of tabular and graphical presentation.

### Graphs

Graphical aids noted in the literature reviewed included computing charts or *abacs*, alignment charts or nomographs, slide rules, and other adaptations of graphs to computation. Computing chart, *abac*, construction was described by Peterson and Gulliksen (113). Crow (34) developed a chart of Chi-square and *t* which facilitates interpolation for routine work. Schutzenberger's (117) *abac* of the sample range should enable the computer to apply tests of significance more rapidly but less rigorously than by using the Pearson and Hartley tables (111).

The construction of alignment charts is described by Bond (19), Douglass (39), and Young (143). Hamilton (63) presented a nomograph for the tetrachoric correlation coefficient. Specialized graphical calculation of statistical problems was illustrated by Levi (98), Dufrenoy and Goyan (40), Goyan (58), and Hayes (70).

Some interesting slide rules were developed. Merrill (102) invented a slide-disk calculator for computing root mean squares which bears a striking resemblance to the cylindrical slide rule. The most interesting and potentially useful slide rule for statistics is the film slide rule described by Stibitz (120). Each scale is printed on separate 35 mm. film about 220 feet long. Accuracy is obtained by using the teeth of the sprocket as the unit of measurement rather than the printed scale. The film simply counts the sprocket teeth that pass under a fixed mark, and the scale measures fractional parts of the distances between sprocket teeth. The rule has been made in sizes from three to ten films on each rule with appropriate mechanical connections between sprockets. It has been found to save 80 to 90 percent of the time required for computing over the use of tables and desk calculators.

Callender (24) showed how a simple differential equation could be solved rapidly by using a hatchet planimeter. The ease of constructing such a device may stimulate thinking relative to its application to the integration of empirical curves.

Fiske and Dunlap (50) described a graphical test for significance or differences between frequencies of different samples. Zimmerman (145) reported on apparatus for making orthogonal rotations by projecting coordinates from one plot to another.

### Computational Methods and Formulas

Variations of computational procedure involved derivation of new formulas, improvements in matrix calculation and error determination, changes in methods of computing, and the computation of some new statistics.

Guttman (62) described a method for inverting any nonsingular matrix by building the inverse out of inverses of successively larger submatrices. This is a variant of the contribution attributed to Schur. Satterthwaite (116) demonstrated that the solution of a large set of simultaneous

equations and the inversion of matrices was complicated by errors due to rounding. If the norm of the matrix was less than 0.35, operations involving the inversion were in a state of error control for Doolittle calculation.

Berry (14) showed that the order in which the elements of the matrix are arranged is important. An arrangement in which the diagonal terms are large and the off-diagonal, especially the post-diagonal terms are small, favors convergence for the iterative method. Bruner (20) came to essentially the same conclusion empirically, and indicated that in the Doolittle solution the check column gave closer agreement if the equations were arranged so that the elements of the principal diagonal increased in going from upper left to lower right. Leavens (94) considered the same problem.

Waugh (138) gave a simple illustration of Hotelling's method of inverting a partitioned matrix by partitioning a square matrix of  $2p$  rows into four square matrices. The inverse was also written as a partitioned matrix. Multiplying the original by its inverse gave four matrix equations which were solved for the four elements. Waugh (137) also presented a formula for computing partial correlation coefficients which is new and should save computational effort. Jenkins (82, 83) considered a systematic arrangement of computation for multiple and partial correlation. Kossack (91) presented a model to be followed in computing many zero-order correlation coefficients from a correlation matrix. Weichelt (140) considered a method of estimating correlation coefficients by expressing  $r$  as the ratio between two differences in sums of the dependent variable computed only for extremes of the bivariate distribution. Waugh and Dwyer (139) illustrated compact efficient computation of the inverse of a matrix. Dwyer (43) described a square root or compact method for computing correlation and regression. (By compact he means that the operations are so designed that the machine used carries out many computational steps as a single machine operation.) This is an approximation method and subject to the errors discussed by Satterthwaite (116).

Norton (110) considered calculation of Chi-square for complex contingency tables. He presented a scheme of successive approximations which made the computation systematic. The method provided comprehensive analysis of the contingency table since the interactions as well as the main effect were studied.

Voss (136) described a short-cut for comparing the effectiveness of two methods where a number of experimental conditions were involved. The frequencies of differences between pairs on each condition were tabulated and Chi-square was computed to determine significance of the distribution of differences.

Cowden (32) gave a simple illustration of the application of sequential sampling to an educational problem. In sequential sampling the items are tested one at a time and a decision is made as soon as enough data have been accumulated to justify the decision. One does not know in advance how many items will be needed. The illustration concerned a true-false

examination given to decide the student's grade. Good and poor students could be discriminated quickly, so that the illustration was concerned with borderline discriminations. The goal was to reduce the number of questions asked of the student to a minimum and at the same time control the probability of passing a poor student or failing a good one.

By use of "systematic statistics," Mosteller (106) proposed an analysis for large masses of data where the cost of collecting the data was inexpensive compared to the cost of analysis by efficient procedures. Most of the work could be done with a counting sorter. Procedures were given for estimating the mean, standard deviation, correlation coefficient, and the efficiency of each estimate was discussed.

Horton (76) indicated how large sets of random numbers might be obtained thru compound randomization by using a binary rather than a decimal system of numbers. A scheme for reducing symbol bias in shifting back to decimal numbers was discussed. It was proposed that electronic or electrical systems actuated by cosmic rays and the use of tabulating equipment seemed to be feasible for turning out large amounts of random numbers.

Specific computational developments relating to factor analysis and other statistical technics have been discussed in connection with the computing devices rather than the technics. However, the books by Thomson (131) and Thurstone (132) deserve special mention.

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and the corresponding solution is given by the generalized eigenvalue problem

$$\mathbf{A}^T \mathbf{A} \mathbf{v}_k = \lambda_k \mathbf{v}_k$$

where  $\mathbf{A}^T \mathbf{A}$  is a symmetric matrix. The first few eigenvectors  $\mathbf{v}_1, \mathbf{v}_2, \dots$  are used to represent the data points in a lower-dimensional space. The dimension of the space is determined by the number of eigenvectors used. The resulting coordinates are called principal components.

The first principal component  $\mathbf{v}_1$  is the direction of maximum variance in the data. The second principal component  $\mathbf{v}_2$  is orthogonal to  $\mathbf{v}_1$  and represents the direction of maximum variance in the remaining data. This process continues until all the data points have been represented in the new space.

One important application of PCA is dimensionality reduction. By retaining only the first few principal components, we can reduce the dimension of the data while retaining most of the information. This is particularly useful in image processing and computer vision, where images are often represented as high-dimensional vectors. By reducing the dimension of the data, we can speed up computations and reduce memory usage.

Another application of PCA is feature extraction. By selecting the first few principal components, we can extract the most important features from the data. This can be used for tasks such as classification and regression, where we want to predict a target variable based on a set of input features.

In conclusion, PCA is a powerful technique for dimensionality reduction and feature extraction. It has many applications in various fields, including image processing, computer vision, and machine learning.

# REVIEW OF EDUCATIONAL RESEARCH

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## Psychological Research in the Armed Forces

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This special number of the REVIEW was planned and prepared by the following committee selected primarily because of the close contact of each of its members with the various phases of research conducted in and for the Armed Forces during the period of the recent conflict generally known as World War II.

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## INTRODUCTION

THE PREPARATION of this special number regarding psychological research in or for the Armed Forces was initiated by Alvin C. Eurich, as president of the American Educational Research Association, and the executive committee of the association shortly after the end of World War II. A committee composed of individuals representing several of the various groups of psychologists working on military problems was appointed. The committee agreed that such a review and bibliography could be especially valuable if it were comprehensive and directed attention to the wealth of materials which had not been made generally available and to a large extent probably never would be published in the professional journals. It was also believed that this material could be best reviewed by those who actually participated in the research and were familiar with the essential background and conditions.

Assignments for various chapters and sections were made by the committee and a tentative schedule established. Unfortunately, the pressure of preparing official reports and the extensive personnel shifts during the period immediately after the war necessitated numerous changes both in scheduling and in the responsibilities for reviewing particular materials. In most cases the complete reports were only available in the official files and the committee was therefore dependent on obtaining the cooperation of a small number of individuals who were attempting to carry on the research work initiated during the war. Under these circumstances the assistance of the various collaborators is especially appreciated. The appreciation of the problems and the valuable assistance of the executive committee have been important factors in the completion of this project.

JOHN C. FLANAGAN, *Chairman*

## CHAPTER I

### General Reports of Research Programs for the Armed Forces

JOHN C. FLANAGAN

DURING the period of World War II a large amount of research on psychological and educational problems was conducted in and for the various armed services. Because of military security measures and the pressure of current military duties and problems only a small fraction of this research was published in professional journals or otherwise made generally available during the war. The purpose of this review is to bring to the attention of research workers the nature and scope of the research studies conducted so that the experience and findings of the wartime studies may be summarized in a single source.

One of the first groups to become actively engaged in military research in the period preceding the entry of this country into the war was the committee of the National Research Council established at the request of Dean R. Brimhall, Director of Research, Civil Aeronautics Administration. The research in aviation psychology of this group has been reported in a series of Research Reports published by the Civil Aeronautics Administration. The findings of this series of studies have been reviewed by Viteles (5) and are not included in the present survey. This group, of which M. S. Viteles is chairman, is continuing an active program of research. It is now known as the Committee on Aviation Psychology of the National Research Council.

A number of those most active in the early stages of the program discussed in the preceding paragraph entered the Navy after our entry into the war and an Aviation Psychology Branch was established under the direction of the late John G. Jenkins in the Bureau of Medicine and Surgery in the Navy Department in Washington. The reports of this group are reviewed by Ames and Older in Chapter II of this survey. This work is continuing in the same location under the direction of Lieutenant Harry J. Older.

The research program in aviation psychology reviewed by Frederick B. Davis in Chapter III was initiated in the summer of 1941. The research results of this group have been reported in a series of nineteen research volumes under the general title of Army Air Forces Aviation Psychology Program Research Reports (3). The scope of this program has been expanded and it is continuing under the direction of Glen Finch, Acting Research Chief, Division of Human Resources, Office of Research and Development, Headquarters, United States Air Force.

The Adjutant General's Office in the War Department established a Personnel Procedures Section under the technical direction of Walter V. Bingham in the fall of 1940. The numerous research studies carried out

by this group have had very little circulation outside of the staff of this group. Therefore the review of these studies by Sisson in Chapter IV should be especially valuable in bringing to the reader's attention work done under the supervision of Marion W. Richardson, Edwin R. Henry, and others who directed this work. This work is continuing under the direction of Donald E. Baier.

The program on personnel research and test development in the Bureau of Naval Personnel did not get started until late in the fall of 1942. The organization was directed by Alvin C. Eurich initially. He was succeeded by Raymond Faulkner. The work is being continued under the direction of Eugene D. Carstater. The work of this group has been reported in a volume (4) edited by Dewey B. Stuit. It was originally planned that this material be reviewed by one of the group who worked in the program. This proved to be impossible. The reviews of the published reports of this group are therefore included in the miscellaneous chapter.

Throughout the war a substantial amount of research on personnel problems was conducted for the Navy by the National Defense Research Committee thru its Applied Psychology Panel. John M. Stalnaker was chairman of the original committee set up to handle this work. He was succeeded by Walter S. Hunter when the panel was formed. This group contracted with various universities and other organizations to carry out specific research and development projects requested by the armed services. The reports of these groups are listed in a bibliography prepared by Bray (1). An official summary report has also been published in two volumes (7). One is on aptitude and classification, the other on training and equipment. Both are edited by Wolfe. Another more popularly written account of the work of these groups has been prepared by Bray (2). Plans for the review of this work by personnel participating in the program could not be carried out and the published reports of this group have also been included in the reviews of the miscellaneous materials.

In addition to the work done under the supervision of the Applied Psychology Panel there was a substantial amount of research done by civilian organizations under other auspices. One of the largest of such programs was the work of the Psycho-Acoustic Laboratory at Harvard University under the direction of S. Smith Stevens. A review of the work of this group is given in Chapter VI.

Another program including a number of psychologists was the service work in assessing candidates for assignments for the Office of Strategic Services. This has been reported in a recently published volume prepared by a group of staff members (6).

One additional set of reports on psychological work done in the services during the war is to be published. This is an account of the work of the Morale Services Division. This work was initiated by Major General Frederic Osborn and was carried out under the immediate supervision of Samuel S. Stouffer and Carl I. Hovland. The four volumes reporting the findings of this group are expected to be available soon.

A number of psychologists rendered valuable services in many other connections during the war. Published reports of many of the studies done under their direction are briefly reviewed in Chapter V. It is believed that a small number of important research studies carried out for the services during World War II have been overlooked. However it is hoped that thru the many reports listed in this review, research workers will be able to benefit from most of the valuable studies carried out during this period.

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## CHAPTER II

### Aviation Psychology in the United States Navy

VIOLA CAPREZ AMES and HARRY J. OLDER

THE INVESTIGATIONS reported in this chapter have been selected as representative of both the type and the scope of the work developed by the psychologists in the Aviation Psychology Branch, Bureau of Medicine and Surgery, Navy Department, under the direction of Captain John G. Jenkins. Much of the work of the Branch was of an advisory or applied nature which did not lend itself to written reports. Consequently, many aspects of the program are not in written form.\*

The development of the naval aviation psychology program up to and following the time of the establishment of the central office in October 1942 may be read in several descriptive summaries (7, 8, 14, 15, 16, 32, 40). Psychologists were originally commissioned to administer, score, and interpret tests for the selection of naval aviation cadets; however, the program soon broadened to include the development of experimental designs for research projects, statistical analyses, methods for selecting flight instructors and aircraft gunners, investigation of attrition, development of training aids, advisory aid to other bureaus, and research on vision and communication.

The principal research groups in the naval aviation program were at Washington, D. C.; Pensacola, Florida; Corpus Christi, Texas; and Jacksonville, Florida. The Washington group was primarily occupied with the administration of the program, the validation of the tests, the development of improved criteria, and consulting services. At Pensacola emphasis was on the investigation of problems of night vision training, disorientation, and intelligibility. Studies on fear and leadership were conducted at Corpus Christi. The Aviation Gunnery Group worked on the development of uniform curriculums for gunnery schools, improved grading systems, and tested special devices (7, 8, 27).

#### Selection and Classification

About a year and one half before the Pearl Harbor attack, work had begun on the validation of a group of tests for the selection of naval aviators. From the forty different tests investigated, three were selected. Each of these three tests was validated on groups of over 3000 cadets (44).

The three tests originally used were the *Wonderlic Personnel Test (PT)*, the *Mechanical Comprehension Test (MCT)*, and the *Biographical Inventory*. In October 1942 the *Wonderlic Personnel Test* was replaced by the

\* The statements contained herein are the personal interpretations of the writers and are not to be construed as reflecting the views of the Navy Department or the naval service at large.

*Aviation Classification Test (ACT).* Two forms of this test were developed by the members of the Aviation Psychology Branch in such a manner as to give maximal spread and maximal reliability in the region of the cutting score (31, 23). Both forms had estimated odd-even reliabilities of over .92.

Early investigations indicated the ability of the *Wonderlic Personnel Test* to discriminate between trainees who pass or fail (in aviation training) among low-score groups. However, this was not true for the middle and upper score-range groups. The *Personnel Test* was found to be most valuable for predicting ground-school failures (6). Like the *Personnel Test*, the *Aviation Classification Test* was found to predict academic failures (ground-school training) fairly well, but to be of no value in predicting flight-training failures. Biserial correlations of .29 and .38 are reported for the *Aviation Classification Test* based on all entrants into training versus ground-school training failures.

New forms of the *Mechanical Comprehension Test* were developed by the Psychological Corporation for use in the naval aviation selection program. The estimated odd-even reliability was .80. The test-retest coefficients varied from .84 to .87. That the *Mechanical Comprehension Test* predicted failures for both flight- and academic-training groups is evidenced by the biserial correlations presented by Fiske (6). These range from .14 to .43 for flight training and from .15 to .48 for ground-school training.

The *Biographical Inventory* is a questionnaire with items on biographical information, interests, habits, and attitudes (6, 14, 38, 41). It was originally developed for use in the selection of civilian pilots, but was later adapted to naval aviation selection.

The test-retest reliability was approximately .70 for a group of almost 2000 men. The biserial correlations for the *Biographical Inventory* reported by Fiske (6) range from .15 to .40 for flight-training failures, .06 to .28 for ground-school failures, and .21 to .36 for all failures.

One of the most significant technical advances made in 1942 by the Aviation Psychology Branch was the introduction of a single index to represent various combinations of test scores. This index, called the *Flight Aptitude Rating (FAR)*, combined the grades on the *MCT* and the *BI* (14).

Originally, a table was constructed to show the percent of failures among men obtaining each of the possible combinations of *BI* and *MCT* scores (18). Cells with similar percents were grouped into one of five categories of progressively high failure rates. Later, the scale was divided into nine steps to permit finer discriminations. The biserial correlation between pass-fail groups and the *FAR* was .43. Since this value was exactly the same as the multiple R between pass-fail and the *BI* and *MCT*, it indicated that the *FAR* made the maximum use of differentiations provided by the tests (6).

Early in the program it was found that age correlated with outcome of training. The younger cadets were more likely to graduate than the older ones. It was also evident that extent of previous flight training predicted

outcome of training, but not as well as either the *BI* or *MCT*. As for education, cadets with no previous flight training and less than two years of college showed a significantly higher percent of failures than those with no previous training but at least two years of college (6).

Success in the development of technics of selection for naval aviation cadets suggested the feasibility of similar technics for the selection of flight instructors. *Technical Memorandum No. 7* (39) outlined the approach to the project. The steps, in order, were: (a) to identify two groups of flight instructors representing the "tails" of the distribution of instructor ability; (b) to determine specific characteristics which discriminate between these extremes; (c) to develop a scoring key and check its validity. The tests used were: *PT*, *MCT*, *BI*, the *Aviation Preference Check List*, the *Opinions on Flight Instruction Inventory*, and the *Aviation Experience Record*. The last three tests were developed expressly for this study. Data were completed on 905 instructors. Five types of criteria were established. As a result of this study the *Instructor Aptitude Rating Scale* was devised for the selection of instructors.

Trumbull and Vinacke (29) reported an evaluation of the *Diagnostic Scale for Rating Flight Instructors*. The scale was composed of thirty-five items in terms of which a student was asked to assess the merit of his instructor. Thirty-four instructors from two squadrons were used in the trial groups. The results indicated that the five degrees along the scale were far from equal for all questions; several questions were unsatisfactory in terms of consistency of the scale, but the majority of the items were relevant. A revised questionnaire was developed as a result of the study.

An analysis of flight instructor selection technics was reported by Trumbull and Vinacke (28). Well-defined criterion groups of "good" and "poor" instructors were compared. Differences between the groups on components of selection tests were evaluated with the conclusion that the type of material used in these tests was of value in selecting instructors, but a majority of the items did not give the best prediction for the population used in this study.

The Pensacola group worked on questionnaires for selection for advanced training. Many different criteria were used for selection purposes. One of these, low pressure tolerance, was eliminated after completion of Research Project R7-2 on classification tests in low pressure chamber (27).

### Training

The aviation psychologists who were attached to the Naval Air Training Commands were engaged in a variety of training projects. Among their contributions were: (a) the development and introduction of improved training records, forms, and procedures; (b) aid in the preparation, evaluation, and revision of syllabi and training manuals for both flight- and ground-school instruction; (c) the improvement of testing methods and grading procedures; (d) statistical analyses of such factors as student

flow, causes of attrition, and comparison of records from different training stations (7, 8, 14, 15, 16, 27).

Considerable work was done on the standardization of flight instructor's vocabulary as one of the basic problems of naval aviation training. A technic was developed which permitted sound recordings of all conversations between instructor and student during an instructional flight. The apparatus consisted of a two-way electrical interphone which also served as a modulator for a light-weight high-frequency transmitter. Thru this device it was possible to "listen in" and make recordings on the ground of conversations in the air. These conversations were typed and studied in detail. From the results the "Patter" book for flight instruction was written (19).

At Pensacola various analyses of attrition were made. Among the reports are: "Analysis of Attrition Trends in Aviation Cadets," "Chronological Analysis of Requests To Be Dropped from Training," and "Analysis of Attrition—Primary Land Planes" (27).

A second major function of the Pensacola group was the investigation of visual problems in naval aviation training. Studies of night vision testing instruments, new color testing devices, and night vision training procedures were carried out.

A preliminary report on "Loss of Visual Contrast Discrimination" includes the following statement: "Loss of visual discrimination can be both predicted and measured under conditions of mild anoxia. The particular form of the test (Hecht) is unsatisfactory due to the large proportion of men failing to show the anoxia effect, or failing to comprehend the instructions" (27).

The autokinetic illusion was studied in the laboratory with light stationary, light and/or subject moving, and in night formation flights. Autokinesis is universally experienced by normal persons; the delay in onset with a single light is short. Movement, in one direction, lasts about ten seconds. A single spot is seen to move about half the total fixation time. The illusion is only slightly subject to voluntary control. Increasing the frame of visual reference reduces but does not readily abolish the illusion, and it is reduced by more adequate spatial localization of object, by rapid relative movement of the target, and by shifts in attention. "The Autokinetic Illusion and Its Significance in Night Flying," by Graybiel and Clark (10) reported these findings.

An investigation of the role of vestibular nystagmus in the visual perception of a moving target in the dark by Graybiel, Clark, MacCorquodale, and Hupp (12) is an extension of the above study. Six subjects reported their visual perceptions both during and following rotation while observing a moving target in the dark and in a lighted room. When a subject was accelerated to 15 rpm in the dark, there was a rapid displacement of the target in the opposite direction, altho, at the same time, as a result of nystagmus, the target appeared motionless. Following cessation of rotation to the *right* at 15 rpm the target appeared to move very rapidly to the

left. Following cessation of rotation to the *left*, the target appeared to rush rapidly to the right while it was displaced to the right very slowly.

These phenomena, which did not occur in a lighted room, can be considered as a summation of the effects of real motion of the target, vestibular nystagmus, and the subject's sensation of their own motion. These effects have important implications in the explanation of "vertigo" in pilots.

An analysis was also made of the concept of aviator's "vertigo," based upon personal interviews with Naval aviators by Vinacke (48). He concluded that "the term 'vertigo' as used by aviators covers a wide variety of events occurring under many different conditions of flying. The term 'vertigo,' as used by pilots, should be accepted as referring to any sensation, or feeling, which does not accord with observable environmental facts."

The oculogyral and oculogravic illusions were studied in flight using three subjects who observed a fixed luminous target in the dark. Observations were made in the rear cockpit of a standard navy training plane. The subject gave a running account of the apparent motion and displacement of the target while the pilot maneuvered the plane thru different degrees of bank (3).

Studies from the Pensacola laboratory have demonstrated several illusions of movement which may occur in flight. Three of these, the autokinetic illusions, the oculogyral illusion, and the oculogravic illusion were studied extensively.

Vinacke (49) reported a detailed description of the types of illusions reported by a large number of pilots as occurring in aircraft. The illusions described by the aviators were categorized into five general types: visual, nonvisual, conflicting sensory cues, dissociational or recognitional, and general emotional.

The speech intelligibility research program at Pensacola was initiated in 1942. Preliminary research indicated a need for more thoro analyses of the factors contributing to poor intelligibility of voice communications. One study of 200 instructors disclosed that only 14 percent had poor phonation (loudness, pitch, quality), in normal conversation, but 80 percent had poor phonation under simulated flight conditions.

The researches on speech intelligibility covered the message, the talker, the transmission system, and the listener. Early in the program it was noted that certain words have a better acoustic penetration in noise. A study of vocabulary used by gunners in intercommunications procedure revealed that some words had less than 10 percent intelligibility value. Another observation revealed that long words had higher intelligibility value than short words (45).

Speech technics have been developed to improve aerial voice communications. Two types of transmission systems have been studied: (a) the Gosport (acoustical) and (b) the Radio (electrical). Intensive studies of the Gosport speaking type system led to modifications which improved intelligibility of voice transmission. Microphones, earphones, and oxygen masks have been studied, also. The speech laboratory has developed various

methods to check listening ability during flight. It found little relationship between audiometric examination results and listening ability in noise (22, 23, 45, 46).

Steer, Lawrence, and others (24) reported an evaluation of the Gosport speaking tube. Flight and laboratory tests were conducted to evaluate the relative advantages of the old and new Gosport. An experimental feedback system which allowed the instructor to hear himself talk to the student was also tested.

The speech intelligibility training program was described in detail by Steer and Hadley (23). They also gave a bibliography of the research projects completed in the laboratory.

### Measurement of Proficiency (Criteria)

The Washington group early recognized the lack of systematic treatment of the criterion-to-be-predicted problem. They concerned themselves with efforts to establish methods of collecting and recording criterion data, with the investigations of factors influencing the reliability and validity of the criterion and with the development of technics of analysis. Jenkins (17) in a recent article summarizes the thinking of the group on the more pertinent aspects of the problem.

The principal criterion used for the validation of the various selection devices was outcome-of-training (the award of the "wings" or the dismissal from training). Outcome-of-training was further refined into reason-for-failure, such as ground-training failures, psychologically unsuited, dropped at own request, etc. These criteria naturally, were neither highly reliable nor valid for the prediction of combat pilot success (6, 14, 17).

The first attempt to obtain combat criterion data was made by four naval psychologists who interviewed pilots with combat experience as they returned to the United States. Approaches considered and/or attempted were: (a) to determine what characteristics were important in meeting combat-requirements, (b) to obtain ratings or rankings of all members of an air group, (c) to use decorated versus undecorated pilots, and (d) to use number of planes shot down. It was finally decided to attempt to identify men regarded by fellow pilots as either definitely wanted or definitely not wanted as a member of their combat team.

A member of the Aviation Psychology Branch was sent to the Pacific area to develop basic methods of obtaining combat criterion data. The "high" nominations were sought by asking the respondent to name two men of his acquaintance (living or dead, regardless of rank) on whom he would most like to fly wing in combat. Nominations for the "low" group were obtained by asking him to name two men whom he would not like to have flying wing on him in combat (47).

Further nominations were collected by one psychologist at a west coast port and by four psychologists in the Pacific area. Over 800 respondent pilots with approximately 1600 high and 1600 low nominations were contacted.

The free-response data were later categorized for coding. The original thirty-three unit-categories were reduced to twenty-six. These twenty-six categories when sorted formed five category-clusters (33, 34, 42, 43).

From these categories two checklists were constructed, one for the high or "wanted" pilots and one for the low or "unwanted" pilots. The checklist method yielded 2872 respondents with a total of 4325 nominated pilots. Of these nominees, 2267 were nominated as highs, 1832 were nominated as lows, and 226 pilots were nominated for both high and low by different respondents. The fact that so few pilots received conflicting nominations is taken as evidence of the validity of the nomination technic (35, 36, 37).

In a report of the Combat Criterion Project to date, Carroll (1) reported on the preliminary work, the technic for coding free-response materials into categories, the use of sociometric diagrammatic technics, experimental design, and nature of the population.

An incidental investigation was made of the relationship of frequency of response to importance of response. The results indicated considerably less than a perfect correlation (43). This may have implications for future research.

Trumbull and Vinacke (30), concerned with the problem of a criterion for the validation of flight instructor selection tests, used student evaluations of their flight instructors to establish criterion groups for analysis of selection data. The agreement among six criteria of success was determined, and the 20 percent of instructors rated best and 20 percent rated low were isolated. The six criteria showed agreement. Using a composite of these six, the extremes of flight instructors were defined.

Another approach to the criterion problem was made in the validity study of five targets for testing visual acuity thru the correlation of the test results of each target with the Grow Chart scores. In addition, the test-retest reliabilities of all six tests were studied. Acuity scores, obtained in Snellen equivalents, were translated into log-units to facilitate statistical analysis. Additional systems were assayed for scoring each of the Randolph Field tests (26).

Estimates of the reliability of the Verhoeff test of depth perception were computed in a test-retest study (25). Four scoring methods were studied for their relative reliability and discrimination between levels of depth perception.

### Attitudes, Morale, and Leadership

The Corpus Christi group became interested in basic emotional and social problems. One product was a discussion of the psychology of fear with emphasis on how to counteract it. A survey of attitudes and information regarding the war was made. The problem of leadership and organization in patrol plane crews was brought out for examination and treatment (8).

A preliminary questionnaire study was made of the feasibility of using

the nominating technic at preflight schools for evaluating leadership and associated qualities of aviation cadets and student aviation pilots. Two questions were asked: "What two men in your present platoon would you select as leaders for the new one?" "What two men in your present platoon would you least desire as leaders of the new platoon?" (31).

### Tabulating and Analysis Techniques

Much of the work of the naval aviation psychologists consisted of the development of technics of analysis. Unfortunately little of this work has been put into written form.

At Pensacola, Graybiel, Clark, and MacCorquodale (11) reported a method for observing and reporting the effect of angular acceleration and variations in "g" on visual perception during flight. The visual stimulus was a collimated "star" installed in the rear cockpit of a standard navy training plane. All observations were made in complete darkness. Both the pilot's and observer's verbal reports were dictated into an airborne wire recorder which also provided a time limit. These recordings were transcribed in the laboratory, and all analyses made from them. Fiske and Dunlap (9) presented a graphical test for the significance of differences between frequencies from different samples.

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## CHAPTER III

### Psychological Research in the AAF Aviation Psychology Program

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THE REPORTS of psychological research reviewed in this chapter were written by military and civilian personnel of the Army Air Force Aviation Psychology Program. These reports are all in published form; originally, the reviewer had hoped to include unpublished research reports (of which hundreds are on file), but several considerations made this inadvisable. In the first place, the nineteen *AAF Aviation Psychology Program Research Reports* which were listed by Flanagan (27) include most of the important research findings that were presented in the unpublished documents and that are not subject to restrictions for security purposes. In the second place, the task of reviewing the unpublished materials and assigning credit for the research reported in them proved to be prohibitive.

In addition to the officially approved reports and articles reviewed, this chapter includes a few others that present results of research conducted in the AAF Aviation Psychology Program.

Two articles that were written by personnel of the AAF Aviation Psychology Program about aviation psychology in enemy countries indicated clearly that in this field the air forces of the United States and its allies were far ahead of the German and Japanese air forces. Fitts (22), who served as official representative of the AAF Aviation Psychology Program on a mission to Germany for the purpose of studying the technics and procedures used by German Air Force psychologists during the war, reported that concepts of objectivity, standardization, reliability, and validity were almost completely disregarded by the German psychologists. So far as could be determined, no contributions to technic were made that would be of value to American psychologists. Geldard and Harris (35) visited Japan in November and December of 1945 to assess the work of psychologists in the Japanese Air Forces. They found that both the Japanese Army and Navy Air Forces used batteries of paper-and-pencil tests and psychomotor tests to select men for pilot training. In general, it is interesting to note that, so far as aviation psychology is concerned, Japanese psychologists seemed to be far more advanced than their German counterparts.

It is not generally known how considerable were the contributions of the AAF Aviation Psychology Program to air-crew selection procedures employed by the Royal Air Force, the Royal Canadian Air Force, the Australian Air Force, and the South African Air Force. Special air-crew classification batteries were actually designed for use in the French, Chinese, and Philippine Air Forces. Lyerly (70) has discussed the preparation and use of these batteries in some detail.

## Organization and Development of the AAF Aviation Psychology Program

In Report No. 1 of the AAF Aviation Psychology Program Research Reports, Flanagan (25) described the development of the program, its main findings and accomplishments, and their implications for psychology and education. Following a brief introduction (25, Chapter 1), he presented the historical background (25, Chapter 2) essential for an understanding of the program and quoted official directives concerning it (25, Chapter 3). The objectives of the AAF Aviation Psychology Program were stated in 1943 and again in 1945 in articles in the *Psychological Bulletin* (81, 82). The organization and personnel of various research units were also discussed in these articles. Thorndike (101) has summed up the psychological research work in the AAF Aviation Psychology Program under two headings: first, the development and validation of tests for use in selecting and classifying air-crew personnel; and second, the solution of problems required to maximize the combat efficiency of personnel.

Activities of psychologists in the AAF Training Command and some of the results of their work were described in an article prepared by the staff of the Psychological Section, Headquarters, AAF Training Command (89). DuBois (18, Chapter 2) outlined the location and functions of the psychological units in the Training Command and Gilmer and Preston (37, Chapter 8) mentioned some of the administrative problems encountered in their operation. Simon and Berwick (96, Chapter 16) provided information concerning the special services performed during the war by the Statistical Unit of the Psychological Branch in the Headquarters of the Training Command.

In addition to units in the continental United States, several detachments of psychologists were sent overseas for temporary duty. The histories and objectives of these detachments and of other missions undertaken abroad by members of the AAF Aviation Psychology Program were summarized by Lepley (66, Chapters 1, 2). In general, the detachments obtained combat validation data for test scores, made analyses of combat requirements, studied the aptitudes required of lead-crew personnel, and developed proficiency measures for air-crew specialties.

### Selection

In the first published account of work in the AAF Aviation Psychology Program, Flanagan (28) reported the initial steps in developing a test for selecting air-crew members in the AAF. This test, first called the *Aviation Cadet Qualifying Examination* and later the *AAF Qualifying Examination*, was further described in subsequent publications (25, Chapter 4; 80), and particularly in a volume edited by Davis (14). The latter traced the development of the *AAF Qualifying Examination* over a period of four years (14, Chapter 1), described the research work underlying its develop-

ment (14, Chapter 3), and made a general evaluation of its usefulness to the Army Air Forces (14, Chapter 12). The principles employed in constructing this *Qualifying Examination* were set forth in some detail (14, Chapter 2) and should prove of interest to technicians confronted with the problem of assigning individuals to "accepted" or "rejected" groups without regard to individual differences within each group so obtained. The *Qualifying Examination* was constructed to serve a particular purpose, tho it found many uses (14, Chapter 4).

In seven successive chapters of AAF Aviation Psychology Research Report No. 6, Davis (14) reported research on many kinds of test items tried out for use in the *Qualifying Examination*. Of three types of verbal items, reading-comprehension items were most useful for predicting graduation or elimination from pilot training in the AAF (14, Chapter 5). Factorial studies suggested that word knowledge and reasoning in reading are two important skills involved in reading. This result agreed with prewar studies by Davis. Successful efforts to develop tests of factual information that measure interests significantly related to graduation or elimination from pilot training in the AAF were described (14, Chapter 6). The technics employed should prove applicable to the construction of tests for educational and vocational guidance.

Objective test items that measure judgment and reasoning were found by Davis (14, Chapter 7) to be factorially complex. Several reasoning factors were identified, one of which was significantly related to graduation or elimination from pilot training in the AAF. A mental skill believed to be peculiar to what is known as "judgment" was determined and named "evocation," the ability to call relevant information to mind.

The most useful items for predicting performance in pilot training were said by Davis (14, Chapter 8) to be mechanical-comprehension items. An investigation revealed that their variance could be accounted for almost entirely by four independent factors. The design of the factorial study was novel and should be of interest to students of factorial analysis. The usefulness of twenty types of machine-scorable perceptual-test items for predicting graduation or elimination from pilot training in the AAF was discussed by Davis (14, Chapter 9), and methods for ascertaining their efficiency in combination were outlined. Other types of items for which validity data were reported by Davis (14, Chapter 10) included mathematics items, interpretation-of-data items, and printed psychomotor items. The latter were especially recommended for additional research.

The Victory Corps *Aeronautics Aptitude Test* which was widely distributed by the U. S. Office of Education was constructed under Davis's supervision and was described by him (14, Chapter 11). General procedures for devising and refining aptitude-test forms were discussed by Thorndike (101, Chapter 3).

The psychological research on the selection and training of bombardiers in the AAF that was accomplished prior to the establishment of Psychological Research Unit (Bombardier) was summarized by Johnson (55,

Chapter 2). Research on the selection of instructors for bombardier schools was reported by Larson (64, Chapter 7), including data that indicated substantial validity for the Instructor-Selection Stanine. Melton presented (73, Chapter 23) information concerning the validation of eight apparatus tests against criteria of performance in bombardier training.

McClelland and Dailey discussed the correlations of twenty-two scores derived from the *Air-Crew Classification Battery* with five criteria of proficiency in flight-engineer training (71, Chapter 5). Intercorrelations of a number of tests constructed especially for selecting flight engineers and tests in the *Air-Crew Classification Battery* were also reported. A complete report on the problem of selecting flight engineers was made in the volume edited by Dailey (13), including a summary of the research up to 1946 and suggestions for future work in the field (13, Chapter 6).

Six phases of the problem of selecting gunners were described by Stolurow and Schrader (98, Chapter 6). Difficulties in obtaining satisfactory criterion variables and practical limitations that prevented the elimination of more than a small proportion of trainees were major handicaps. Schrader, Pascal, and Valentine reported the development of a selection test for gunnery officers, which showed a significant positive correlation with performance in the Combat Gunnery Officers Course (93, Chapter 13). The selection and training of instructors in schools for flexible gunners were discussed by Stolurow, Irion, and Pascal (98, Chapter 12). After consideration of a number of possible criteria, gun-camera scores were chosen for use in experimental studies reported by Melton (73, Chapter 21) on the selection of flexible gunners.

Tests used to select men for navigator training and the research data pertaining to them were described by Carter and Michael (6, Chapter 3). The instruments devised to predict performance as an instructor in navigation schools were considered by Zielonka, Rust, and Rosemark (114), together with data regarding their effectiveness in measuring specified criterion variables.

A series of studies relating to the selection and evaluation of instructors in pilot-training courses in the AAF were reported by Galt and Grier (34, Chapter 14). Work on the prediction of performance in pilot training is reviewed in this chapter in connection with the *Aviation Cadet Qualifying Examination* and the *Air-Crew Classification Battery*.

The history of research work on the selection of radar observers was written by Kunzman (61) and the validation of selection tests for radar-observer training courses was discussed by Kelley (57, Chapter 11). Multiple correlations (subject to shrinkage) of .36 to .50 with criteria consisting of course grades were obtained. Apparatus tests administered at Langley field showed, according to Melton (73, Chapter 22), no significant correlations with any one of four criteria of success in radar training. Intercorrelations of the tests, obtained at Carlsbad Army Air Field, were low.

Mollenkopf and Chaplin reported the design, construction, and use of

tests for selecting instructors in the AAF Personnel Distribution Command (77, Chapter 2). Several weighted composite scores (stanines) were derived from these tests. Descriptions of motion-picture tests constructed for aptitude measurement by the Psychological Test Film Unit were presented by Lamkin, Schafer, and Gagne (63, Chapter 5). The tests generally displayed low positive correlations with graduation or elimination from pilot training and contributed so little to the prediction of that criterion that the expense of using them for practical purposes could not be justified.

The most rigorous study of the prediction efficiency of the procedures used in the AAF Aviation Psychology Program for selecting men for pilot training was designed by Flanagan (26). The study was unique and should prove invaluable to students of mental measurement. Thorndike reported the detailed results of the study (100, Chapter 5), which was based on the records of a large sample of applicants for pilot training who were admitted to training regardless of their scores on the *Aviation Cadet Qualifying Examination* and the *Air-Crew Classification Battery*. Case studies were made of sixteen men who obtained low scores on the selection tests and yet succeeded in completing pilot training and on fifteen men who obtained high scores and failed in pilot training. Walton presented two of these case studies as illustrations (105, Appendix C).

### Classification

As explained by Flanagan (25, Chapter 4) after initial selection by means of the *Aviation Cadet Qualifying Examination*, men accepted for air-crew training were classified for specialized training as pilots, bombardiers, navigators, gunners, etc. Flanagan outlined the essentials of the classification problem and mentioned the efficiency in the utilization of personnel that can be secured by differential classification. In a volume edited by DuBois (18) the classification program in the AAF was explained in detail. DuBois (18, Chapter 1) recounted the history of and plans for the classification testing of aviation students; in collaboration with Preston, he described the composition of the air-crew classification batteries and certain statistical data derived from their use (18, Chapter 3). Extensive data concerning the validity of stanine scores derived from successive classification batteries were reported by DuBois, Preston, and Peltier (18, Chapter 4). A description of group testing in AAF classification centers and a discussion of the standardization of testing procedures were presented by Gilmer and Preston (37, Chapter 2; 37, Chapter 1). The authors likewise described the personal interviews with aviation students and the criteria used in recommending them for types of air-crew training (37, Chapter 7).

Articles concerning the personnel and organization of Psychological Research Units 1, 2, and 3 appeared in the *Psychological Bulletin* (86, 87, 88). Research activities of the units were also described briefly.

The development of tests for air-crew classification has been summarized in volumes edited by Guilford and Lacey (43) and by Melton (73). These tests were designed for use in the classification battery, the criterion for judging their value was their contribution to the prediction of performance in one or more air-crew specialties, as pointed out by Humphreys (52, Chapter 2) in a discussion of the program of printed-test development. It is reasonable to suppose that quite different judgments of value would have been made had the criterion for judging value been a test's contribution to predicting only that part of an air-crew specialty not present in other specialties for which performance was to be predicted. Yet it is this type of differential prediction that is the crux of the classification problem. In practice, therefore, the *Air-Crew Classification Battery* served as a multiple selection test among men initially selected by means of the *Aviation Cadet Qualifying Examination*.

Following an introduction to tests of intellect and information prepared by Humphreys (52, Chapter 4), Mock described tests of verbal ability (76, Chapter 5), Davis presented data concerning mechanical tests (16, Chapter 13) and mathematics tests (16, Chapter 6), and Fruchter reported the findings regarding a trait called judgment (31, Chapter 8) and the development of information tests (31, Chapter 14). Lacey and Tait reviewed research work on reasoning tests that were not incorporated in the *Air-Crew Classification Battery* (62, Chapter 7) and Zimmerman presented data concerning tests of visualization and offered hypotheses regarding the mental traits measured by these tests (115, Chapter 12). The construction of measures of foresight and planning, and data pertaining to their factorial composition, were discussed by Guilford and Mock (43, Chapter 9). These authors also reported the development of tests of integration, the latter being defined as the ability to pay attention to several variables simultaneously and to respond to a combination of them (43, Chapter 10). Research on memory tests was reviewed by Lipman, Patterson, and Shirley (67, Chapter 11). Evidence of the existence of three independent factors thought to represent aspects of memory ability was adduced.

The outline of plans for constructing perceptual tests was provided by Lacey (62, Chapter 15). Zimmerman discussed the development and factorial composition of perceptual speed tests (115, Chapter 16) while Lacey described the printed tests of form perception developed for possible use in the *Air-Crew Classification Battery* (62, Chapter 17). The nature of eleven tests of size and distance was considered by Lacey and Shirley (62, Chapter 18) and their value as tests of pilot aptitude was mentioned. Lacey and Niehaus (62, Chapter 20) reported efforts to measure the ability to determine one's location relative to landmarks, while tests designed to measure other spatial abilities were discussed and their factorial content hypothesized by Howe and Zimmerman (51). Fruchter (31, Chapter 21) described experimentally developed measures of set and attention.

The general approach to the problem of organizing and presenting material for testing emotion, temperament, and personality was outlined by Guilford (43, Chapter 22). According to Cerf (8, Chapter 23), personality inventories and questionnaires that were commercially available in 1942-1945 failed to yield scores significantly related to performance in pilot training in the AAF. Furthermore, Cerf concluded (8, Chapter 24) that predictions of such performance made by clinicians on the basis of sets of test scores and subjective judgment were of little or no value. A description of the biographical data blank adapted by the AAF from the form used by the Civil Aeronautics Administration and the Navy Bureau of Medicine and Surgery was provided by Mock (76, Chapter 27), who presented evidence of its value. Measures of specific traits of temperament that were developed or tried out in the AAF Aviation Psychology Program were discussed by Davis (16, Chapter 25). Grossman presented data (41, Chapter 26) concerning tests of motivation.

One of the most interesting fields of investigation of the AAF Aviation Psychology Program was that of mass testing with apparatus tests. The history of the development of these tests was recounted by Melton (73, Chapter 1), who has discussed the problems arising in the course of the unprecedented use of apparatus tests and the technics devised to cope with these problems (73, Chapter 2). Melton has summarized (73, Chapter 25) the conclusions reached on the basis of over four years of intensive research. He has also discussed technical considerations, such as methods of determining reliability coefficients for apparatus tests and of obtaining suitable criteria for validating them (73, Chapter 3). The mechanics of testing large numbers of aviation students with psychomotor apparatus were explained by Gilmer and Preston (37, Chapter 3).

Among the standard classification-battery tests for which Melton has provided detailed specifications and elaborate data concerning their reliability and validity were the *SAM Complex Coordination Test* (73, Chapter 4), the *SAM Two-Hand Coordination Test* and the *SAM Two-Hand Pursuit Test* (73, Chapter 5), the *SAM Discrimination Reaction Time Test* (73, Chapter 6), the *SAM Rotary Pursuit Test* and the *SAM Rotary Pursuit Test With Divided Attention* (73, Chapter 7), the *Rudder Control Test* (73, Chapter 8), the *Santa Ana Finger Dexterity Test* (73, Chapter 9), six tests of steadiness designed to measure the effect of emotional stress (73, Chapter 10), and two Pedestal Sight Manipulation tests intended to select men for training as B-29 gunners (73, Chapter 11). It was found experimentally that the psychomotor tests in combination made a significant contribution to the prediction of such criteria as performance in pilot training obtained from the use of paper-and-pencil tests alone. One of the questions left unanswered by research completed during the war was whether paper-and-pencil tests could be developed to the point where the unique contribution of apparatus tests would be too small to warrant the expense of developing and administering them.

In addition to the apparatus tests actually employed in the *Air-Crew*

*Classification Battery*, Melton has listed many others that were still in the experimental stage at the end of the war. He has presented as much data about these as can be released under security restrictions. The tests included six designed to measure compensatory visual-motor reactions (73, Chapter 12), six that measure visual-motor pursuit skills (73, Chapter 13), four path-tracing tests together with variations of three of these (73, Chapter 14), several coordination tests (73, Chapter 15), and nine visual discrimination-reaction tests (73, Chapter 16). Others were seven timing-reaction tests (73, Chapter 17), twelve manipulation and motility tests designed to aid in the selection of bombardiers and radar operators (73, Chapter 18), eight stress tests, one of which (the Falling Hammer) was validated against combat criteria by a detachment in England under the leadership of Lieutenant Colonel Paul Horst (73, Chapter 19), a large number of psychophysiological measures developed and studied extensively by M. A. Wenger (73, Chapter 19), and eight miscellaneous tests including measures of kinesthetic discrimination, foresight and planning, muscular coordination, sway compensation, and stability of orientation, as well as the *AAF Physical Fitness Test*, the *SAM Control Sequence Memory Test*, and the *Minnesota Assembly Test* (73, Chapter 20).

Because of the need for placing air crews of the highest quality in lead planes, considerable research was undertaken to measure the abilities required of men in lead planes. This was summarized by Lepley (66, Chapter 9).

### Training

Research on various aspects of training in the AAF was presented by Flanagan (25, Chapter 6). He discussed the content of training courses, the amount and rate of learning that took place, and the evaluation of training devices. The selection of instructors was also considered. Thorndike mentioned some of the problems of training experiments (101, Chapter 10).

Most of the research work on training problems was undertaken by the AAF Aviation Psychological Research Projects at Training Command installations. An account of the history, organization, and research activities of the Psychological Research Project (Bombardier) was presented briefly in the *Psychological Bulletin* (83) and in considerable detail in the volume edited by Kemp and Johnson (58). The latter wrote a brief background history of the training of student bombardiers and of instructors for bombardier training schools (55, Chapter 1), calling attention to the fact that over 47,000 bombardiers were trained in the AAF between the attack on Pearl Harbor in 1941 and the surrender of Japan in 1945. He also outlined the organization and mission of Psychological Research Project (Bombardier) of which he was Assistant Director (55, Chapter 3). Kemp and Helmick reported an experimental study designed to show the improvement in circular error resulting from increasing the number of bombs dropped during the bombardier training

course (58, Chapter 8). Johnson (55, Chapter 10) summarized the work of the Psychological Research Project (Bombardier) and together with Kemp offered suggestions for future research in aviation psychology (58, Chapter 11).

Psychological research concerning the selection and training of flight engineers began at Psychological Research Unit No. 2; later it was centered in the Psychological Research Project (Flight Engineer) at Hondo, Texas. The research projects undertaken and the trends that influenced their choice were outlined by French, McClelland, and Dailey (29). According to McClelland, Canfield, and Dailey, flight-engineer training was begun in April 1943 when excessive losses of bombardment aircraft on long over-water flights demonstrated the need for an air-crew member trained to operate engines at optimal power settings (71, Chapter 5).

The psychological research carried out on flexible-gunnery training was reported in AAF Aviation Psychology Program Research Report No. 11, edited by Hobbs (50). He has written a brief history of the training of flexible gunners (50, Chapter 1), has pointed out the role of psychologists in the training program (50, Chapter 4), and has made a critical evaluation of the contributions of psychological research to gunnery training (50, Chapter 15). With Schrader (50, Chapter 11), he explained how psychologists prepared curriculums, lesson plans, manuals, etc., for the training courses, formulated principles of program planning, and systematically evaluated the training programs. A description of the typical gunner in the AAF was written by Pascal (79, Chapter 3); the gunner was said to be about twenty-three years of age, a high-school graduate, and about half a standard deviation above average in mental ability. His motivation during training was not good. A description of several training devices used in flexible-gunnery training was given by Vallance and Schrader together with evaluative information pertaining to them (103, Chapter 9).

The establishment of the Psychological Research Project (Navigator) in the AAF Training Command was described by Carter (6, Chapter 4) and a list of the personnel attached to it was presented (84). A complete account of the work of the project was made available in the research report edited by Carter (6), who also prepared a summary of psychological research in navigator training with suggestions for future planning and research (6, Chapter 13). Michael outlined the role of the navigator in the AAF, the selection of men for navigator training, and research in the problems of navigator training (74, Chapter 1). Suggestions regarding the length and arrangement of the content of the course in navigation resulted from a study of dead-reckoning navigation that was made by Dudek (19, Chapter 8). With Glaser, Dudek also reported the nature and results of a rigorous evaluation of a special training aid used in navigation training in the AAF-trainer, the so-called G-trainer. Important methodological implications may be derived from this study.

In AAF Aviation Psychology Program Research Report No. 8, edited by Miller (75), psychological research was reported on objective measures

of flying skill, printed tests of flying information, subjective measures of flying proficiency, job analysis, and instructor selection and evaluation (75, Chapter 1). Prior to this, the functions, history, and personnel of the Psychological Research Project (Pilot) had been listed briefly and its research activities discussed at some length (85). Erickson outlined the organization of the AAF Training Command and briefly described its functions (20, Chapter 2). Two controlled experiments in the training of pilots were summarized by Galt (34, Chapter 13). The results indicated that the use of twin-engine airplanes in basic pilot training improves performance on twin-engine airplanes in advanced training and that the use of optical sights on shotguns used for skeet training is desirable. The effect of adding five weeks of training to the normal courses in pilot training in the AAF was studied and the procedures and results were reported by Miller, Galt, and Gershenson (75, Chapter 10). A summary of the work of Psychological Research Project (Pilot) and recommendations for further work in the field were provided by Miller (75, Chapter 15).

Psychological research on radar-observer training in the AAF was presented in a volume edited by Cook (10). The problems encountered in selecting and training radar observers were mentioned and the procedures employed to solve them were discussed. Cook compared the use of batteries of tests of relatively uncorrelated mental traits with the use of batteries of work-sample tests (10, Chapter 12). As would be expected when two batteries of tests measured essentially the same mental skills in two different combinations, both batteries turned out to provide approximately equal accuracy of prediction; in such a situation, the differences in intercorrelations of the parts of the two batteries could have no appreciable effect on their accuracy of prediction of a single criterion. Hastorf (48, Chapter 1) defined the scope of AAF Aviation Psychology Program Research Report No. 12 and outlined the essential principles of radar, its adaptation to airborne use in combat operations, and the training program for radar observers in the AAF (48, Chapter 2). He also wrote (48, Chapter 3) a brief summary of research on the selection and training of radar observers accomplished under the auspices of the National Defense Research Committee and by Psychological Research Project (Radar).

Studies of the acquisition and retention of air-crew skills were reviewed and some data pertaining to the retention of these skills during periods of inactivity were presented by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 12). The instructional techniques peculiar to the use of motion pictures, together with data regarding their effectiveness as teaching devices, were discussed by Gibson, Borin, Orvis, and Gagne (36, Chapter 10).

### Measurement of Proficiency and Criterion Studies

Studies of the proficiency of bombardiers, flight engineers, flexible gunners, navigators, pilots, and radar observers were summarized by Flanagan (25, Chapter 5). Crawford, Sollenberger, Ward, Brown, and

Ghiselli edited Report No. 16 in the series of AAF Aviation Psychology Program Research Reports, which included data regarding the analysis of duties, the criteria of proficiency used for validation purposes, and the validity data for a number of air-crew positions (12). Their introduction to the report (12, Chapter 1) indicated its scope and purpose. That the most fundamental and, in many respects, the most difficult problem faced in the AAF Aviation Psychology Program was the definition and measurement of satisfactory criterion variables was pointed out by Thorndike (101, Chapter 4). Ultimate criteria were formulated but were rarely measureable. Intermediate or even immediate criteria were therefore used and supplemented with professional judgment. This is an excellent discussion of an important methodological issue. Efforts were made to maximize the relevance of available criteria and to minimize bias in them; of secondary consequence were efforts to maximize the reliability of criterion variables.

Kemp discussed the development of phase checks to serve as criteria for validating tests used in the selection of bombardiers (58, Chapter 4). Proficiency tests were constructed to provide measures of the practical knowledge about bombing and navigation required of bombardier students. These tests were described by Johnson (55, Chapter 5) and sample items were presented. An evaluation of various measures of proficiency for use in bombardier training was reported by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 7). Johnson described (55, Chapter 6) surveys of the level of proficiency of aerial instructors and supervisory personnel at cadet bombardier schools and in the AAF Central Instructors School (Bombardier). Johnson (55, Chapter 9) also reported research on the development of a motion-picture test for target and check-point identification, a study of the reliability of the circular error and of the percent of hits for C-1 autopilot bombing, and the results of several minor studies.

Research work, designed to improve existing criteria for judging the performance of flight engineers and directed at the development of new criteria was described by Seaman, Unger, Dailey, and McClelland (94). The fact that Navigator Stanine scores have some promise for predicting performance in ground-school courses in operational training was indicated by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 8) in studies of criteria for judging the proficiency of flight engineers.

Stolurow stated that the measurement of proficiency among students at gunnery schools was at first ineffective (98, Chapter 7). Gradually, the situation was improved as well-constructed examinations became available and were uniformly administered and interpreted. Data concerning four forms of the *Final Comprehensive Examination* were presented. To meet the need for practical tests of proficiency in operating, caring for, and checking equipment, phase checks were developed, as described by Valentine (102, Chapter 8). A study made by Johnson and Milton (56, Chapter 18) showed that a marked increase in accuracy of aiming a B-29 Pedestal Sight could be secured by redesigning the controls in the light of human capabilities and limitations.

As part of the task of establishing procedures for selecting lead crews, research reported by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 10) was undertaken to provide analyses of proficiency measures and synthetic-trainer scores for flexible gunners in operational training. These editors also reported research on evaluating the proficiency of air-crew members to provide criteria for selecting lead crews (12, Chapter 11).

Research related to the development of aerial measures of navigation skill (97, Chapter 6) and objective ground measures of navigation skill (97, Chapter 5) was described by Smith. Data resulting from studies of the graduation-elimination criterion and of the grades given in navigation schools were reported by Michael and Rosemark (74, Chapter 7). Analysis by Dudek, Peltier, Smith, Lyon, and King of the procedures used to determine position by means of dead-reckoning navigation indicated the relative importance of each of these procedures and provided leads for improving the teaching of dead-reckoning navigation and for decreasing "distance-off" (19, Chapter 9). The duties of the navigator in operational training and criteria for judging his proficiency were presented by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 6).

Problems involved in measuring pilot proficiency were discussed by Miller (75, Chapter 4) while Ben-Avi described the grades assigned to students during their flying training together with analyses and evaluations of them (2). Objective measures of flying skill that were developed for use in primary pilot training were presented by Youtz (113, Chapter 6); objective measures of single-engine instrument-flying skill were discussed and evaluated by Hagin (47, Chapter 9) while Erickson described the nature and use of objective measures of multi-engine instrument-flying skill (20, Chapter 8). Four studies concerning the measurement of pilot skill in flying two-engine airplanes were also reported by Erickson (20, Chapter 7). Fixed-gunnery scores as objective measures of flying skill were evaluated in research studies summarized by Gleason (38, Chapter 11). The development and the use of printed tests of flying information were considered by Robbins and Levine (91). A series of studies on proficiency measures and their validation were reported by Crawford, Sollenberger, Ward, Brown, and Ghiselli concerning the fighter pilot (12, Chapter 2), the photo-reconnaissance pilot (12, Chapter 3), the co-pilot (12, Chapter 5), and the airplane commander (12, Chapter 4). Investigations of fighter-pilot proficiency, the prediction of fighter-pilot combat proficiency, and fatigue factors in long-range fighter missions were summarized by Lepley (66, Chapter 10) from reports written by the investigator, Lieutenant Wilse B. Webb, an aviation psychologist attached to the 413th Fighter Group. Fitts reported the accuracy with which AAF pilots can reach objects placed around them when they are unable to see either the objects or their own bodies (23, Chapter 15). Accuracy is greatest reaching forward and below shoulder level.

Graff, Kelley, and Hastorf discussed the development and content of five

printed tests for measuring the proficiency of students in radar training (39). The intercorrelations of several of these proficiency tests were presented by Kriedt, Johnston, and Kunsman (60), who pointed out the considerable amount of overlap indicated by the data. Six standardized performance tests, developed to supplement the measurement of radar-observer proficiency by means of paper-and-pencil tests were described by Bray (4, Chapter 6). Sources of unreliability in the performance-test scores were discussed (4, Chapter 7) and two concepts of validity were mentioned. The use, reliability, and relationships of the circular error in radar bombing with other measures of proficiency were reported by Klein (59, Chapter 9). It was concluded that thirty to thirty-five hours of training are insufficient to develop a high degree of skill in radar bombing. No satisfactory criteria for validating measures of proficiency for radar observers in operational training were found, according to Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 9).

Gibson reported the construction and use of motion-picture tests for measuring proficiency in aircraft recognition and target identification (36, Chapter 6). In collaboration with Gagne, he presented experimental data on several aspects of aircraft recognition (33). Evaluations of the Renshaw system and of some alternative training procedures were made. Davis described the construction of several specialized examinations used by the AAF, including the *Aviation Cadet Educational Examination*, the *Flight-Officer Examination*, the *AAF English Expression Test*, and the *Victory Corps Aeronautics Aptitude Test* (14, Chapter 11). Experiments reported by Melton (73, Chapter 24) revealed significant impairment of proficiency on both paper-and-pencil and apparatus tests at 15,000 to 18,000 feet without oxygen and at 45,000 feet with oxygen. Performance on an addition test was found especially sensitive to changes in altitude.

In spite of innumerable difficulties, more than 1872 different indexes of the combat validity of the selection and classification tests used in the AAF were obtained. In a research report edited by Lepley (66), these data were reported and discussed. Two faults of criterion data were said by Lepley (66, Chapter 3) to be low reliability and bias. The criteria used included objective measures, administrative actions, direct and systematic observations, and ratings based on general impressions. Lepley described the use of proficiency tests for assembling lead crews and for detecting the need for precombat or refresher training (66, Chapter 8). The tests found to be most predictive for bombardier criteria of combat effectiveness were Spatial Orientation I and II, Mathematics A and B, Mechanical Principles, Discrimination Reaction Time, and the Pilot Stanine (66, Chapter 4). Of thirty-seven variables correlated with several measures of navigator effectiveness in combat, Lepley reported (66, Chapter 5) that sixteen had predominantly positive correlations. The four best predictors were Technical Vocabulary (Navigator), Technical Vocabulary (Pilot), Arithmetic Reasoning, and Mathematics B. The absolute magnitudes of the validity coefficients were not especially meaningful because of marked attenuation

resulting from the rigorous selection of navigators at classification centers on the basis of the Navigator Stanine. A total of 889 validation statistics, using the combat effectiveness of pilots as the criterion, were presented by Lepley (66, Chapter 6). Greatest effectiveness was found for predicting fighter-pilot performance. The most useful classification tests were *Mechanical Principles*, *SAM Two-Hand Coordination*, *SAM Rotary Pursuit*, *Spatial Orientation I and II*, *Aiming Stress* (portrayed on the stage in *Winged Victory*), and *Table Reading*. Criteria of success in combat different from those employed in the studies summarized by Lepley were utilized by Mollenkopf. He found no evidence of significant relationships between the criteria he used and various selection tests (77, Chapter 4). Lepley summarized the psychological research work done in various combat areas by sixteen officers and three enlisted men on temporary duty (66, Chapter 11).

### Studies of Requirements

Studies of the requirements of air-crew positions were made at various times in the AAF Aviation Psychology Program and for many different purposes. Job requirements for the bombardier, navigator, and pilot were reported by Walton (106). Thorndike summarized (101, Chapter 2) the job-analysis procedures employed as a basis for test construction: (a) review of existing literature, (b) analysis of records of performance, (c) interviews with air-crew personnel, (d) direct experience on the part of psychologists, and (e) correlation of tests and criteria.

A description of tasks performed by students in flight-engineer training schools was presented by Schmonsees, Unger, Riecken, and McClelland (92), who also made a job analysis in terms of psychological traits. According to Valentine (102, Chapter 2), the task of the flexible gunner was ordinarily that of firing at a target (an attacking fighter plane) from a platform (a bomber) also moving in three dimensions. A discussion of the skills and abilities involved in gunnery was prepared by Irion (53, Chapter 5), who also considered the use of synthetic trainers as criterion measures.

A job analysis of the navigator's task and the attributes of a successful navigator were presented by Whiteside and Glaser (109). Youtz has provided a convenient summary of the skills and abilities required of a pilot (113, Chapter 3, Part I) and Erickson made an analysis of the pilot's task in specialized types of activities, such as instrument flying, night flying, navigation, and formation flying (20, Chapter 3, Section II).

Kelley reported a job analysis for radar observers (57, Chapter 4) made largely in terms of mental abilities defined by centroid factors to which names were ascribed on the basis of subjective judgment. Investigations of the combat requirements for air-crew personnel were summarized by Lepley (66, Chapter 7), and Flanagan discussed research on mission failures and on errors of personnel during operations in combat (25, Chapter 7).

### Attitudes, Morale, and Leadership

Research on attitudes, morale, and leadership was conducted by the AAF Aviation Psychology Program largely in the AAF Personnel Distribution Command in redistribution stations or convalescent hospitals. Many of the studies made in these installations were summarized by Flanagan (25, Chapter 8), among them investigations of fear and courage in aerial combat, anxiety reactions, counseling and therapy, and attitudes and preferences of combat returnees.

Psychological research on problems of redistribution was summarized in a report edited by Wickert (110). In this report, Wickert recounted the history of psychological research in AAF redistribution stations and listed the personnel engaged in it (110, Chapter 1); he also made an over-all evaluation of the work and mentioned the potential value of data that were gathered but not fully analyzed during the war (110, Chapter 8). Crannell and Mollenkopf outlined the extensive research conducted to determine the essentials of combat leadership (11). Methodological problems of research in leadership were stressed and the instruments used were described. Studies conducted to ascertain the nature of anxiety reactions in combat were reported by Shaffer (95, Chapter 5). The tests used to select air-crew personnel were found to be unrelated to the presence or absence of anxiety reaction as determined by psychiatric examination. A Personality Inventory was developed, however, which consistently showed biserial correlations of the order of .50 with the criterion. With Kamman, Lecznar, Pearson, and Williams, Shaffer discussed surveys of fear and courage in aerial combat, of the psychological causes of mission failures, and of disorientation in instrument flying (95, Chapter 6). The attitudes and preferences of AAF air-crew personnel returned to the continental United States from combat zones were described by Shaffer and Pearson (95, Chapter 7). Differences among fighter pilots, bomber pilots, bombardiers, and navigators were pointed out.

The attitudes and opinions of flexible gunners who had recently returned from combat, had graduated from a training school, or had not entered into combat were reported by Irion (53, Chapter 10). Some of the problems encountered in training navigators who had been returned from combat and assigned to the AAF Instructors School for Navigators were outlined by Friedman, Rosemark, Heathers, Grigg, and Zielonka (30). A study of the attitudes of air-crew personnel (both officer and enlisted) returned from combat toward further duty assignments of various types was described by Crawford, Sollenberger, Ward, Brown, and Ghiselli (12, Chapter 13).

Bijou (3) edited a volume of the AAF Aviation Psychology Program Research Reports concerning research in AAF convalescent hospitals. The need for and development of the psychological services and research work in these hospitals was stated by Bijou and Gillman (3, Chapter 1). The psychological services were described in detail by McNeill, Heathers, Rotter,

Willerman, and Lawrence (72), including evaluation procedures and individual and group counseling technics. Research activities were outlined by Bijou and Heathers (3). The tests and inventories that were used were mentioned and the criteria used to validate them were listed. These same authors also prepared a summary and evaluation of all the service activities and research work of psychologists in the AAF convalescent hospitals (3, Chapter 11).

Data derived from the administration of five personality inventories were summarized by Heathers (49), who concluded that all five of them possessed substantial utility. Lawrence and Levine investigated attitudes of patients in AAF convalescent hospitals (65, Chapter 5) and Lawrence reported data suggesting that biographical information may be useful in making prognoses for convalescent patients (65, Chapter 6). Descriptions of a number of interest questionnaires used in AAF convalescent hospitals and results obtained from their use were presented by Lucio and McReynolds (69).

In an effort to measure the impairment of mental efficiency associated with psychiatric disorders, the *Shipley-Hartford Retreat Scale* for measuring mental impairment and a new *Efficiency of Mental Application Test* were tried out in the convalescent hospitals. Bijou and Lucio discussed the findings, noting that both tests showed promise, particularly the test assembled especially for use in the AAF (3, Chapter 8). Three projective tests were used in the convalescent hospitals by psychologists in the AAF Aviation Psychology Program: the *Rorschach Test*, the *Bender Visual-Motor Gestalt Test*, and the *Incomplete Sentences Test*. Of the three, the last seemed to differentiate best between normal and maladjusted patients. These data were reported by Wischner, Rotter, and Gillman (112). An ingenious method of quantifying interpersonal behavior in group counseling was described by Willerman and Pascal (111) and an illustration of its use was given.

In an article published in the *Psychological Bulletin* (79), Super discussed case studies and clinical evaluations of aviation cadets together with the projective technics employed. The most of the work of the AAF Aviation Psychology Program was concerned with mass testing by means of objective measures, elaborate studies of clinical procedures were made on samples of aviation students in order to assess their efficacy. In general, the data showed that clinical evaluations did not add anything to predictions of performance made solely on the basis of machine-scorable objective tests.

### Tabulating and Analysis Techniques

Elaborate safeguards were employed in test-scoring operations of the AAF Aviation Psychology Program to prevent and catch errors. The procedures used in scoring classification tests were described by Gilmer and Preston (37, Chapter 4). These authors likewise discussed the routine

checks and statistical technics employed to insure comparability in the classification-test scores derived from apparatus tests (37, Chapter 5).

Because validation of test scores obtained at classification centers and psychological examining units against performance in training courses and in certain air-crew duties was the foundation stone of research carried on in the AAF Aviation Psychology Program, it was essential to have an accurate, complete, and convenient records system. Gilmer and Preston described the routine of handling records in psychological examining units (37, Chapter 6) while Simon and Berwick described the records system at the Headquarters of the AAF Training Command (96, Chapter 10), where test scores from many examining units were filed together. The basic records files (96, Chapter 11) and the training-data files (96, Chapter 12) maintained in the Psychological Section at Headquarters, AAF Training Command were also discussed by Simon and Berwick (96, Chapter 13). These authors mentioned everyday problems encountered in the collection and maintenance of machine records and made suggestions for avoiding them (96, Chapter 17). They discussed the types of errors common in machine-records operations and methods used to control them (96, Chapter 18). General considerations in the establishment and use of machine-records systems, with illustrations from their experience in the AAF Aviation Psychology Program, were presented by Simon and Berwick (96, Chapter 9). They also discussed the dissemination of data by means of roster, punched cards, and microfilms (96, Chapter 14).

In AAF Aviation Psychology Program Research Report No. 3 edited by Thorndike (101), some of the technical problems encountered in psychological research work during the war were considered and the procedures developed to meet them were summarized. Special attention was given to problems associated with the selection and classification of personnel. To express validity coefficients, the product-movement  $r$  was used whenever possible. With dichotomized criteria, biserial rather than point-biserial  $r$ 's were computed in order to minimize the effect of variation in the position of the dichotomic line on validity coefficients obtained in different samples. Thorndike discussed these and other correlation statistics used in determining the validity of single tests (101, Chapter 5) and presented the formulas used to correct for restriction of range due to prior selection. Procedures for obtaining composite aptitude scores were outlined by Thorndike (101, Chapter 6). The multiple-regression and multiple-cutoff methods were contrasted and the reasons for choosing the former for use in the AAF Aviation Psychology Program were mentioned. A formulation of the problem of a unique classification system was presented. Emphasis was given (101, Chapter 8) to the significance of the intercorrelations of a set of variables proposed for use for selection purposes. Three types of prediction problems were identified: selection, multiple selection, and classification. The importance of test reliability as an aid to interpreting test-validity data was stressed by Thorndike (101, Chapter 7) and various ways of computing reliability coefficients were men-

tioned. An analysis of the sources of variance in test scores was especially noteworthy (p. 102-103). Several formulas developed by A. P. Horst to determine the loss of test validity ascribable to extraneous variance in test scores were presented by Thorndike (101, Chapter 9). Methods used to minimize extraneous variance in test scores obtained in the AAF Aviation Psychology Program, especially in apparatus-test scores, were found to be highly effective.

Most research workers will want to become familiar with parts of AAF Aviation Psychology Program Research Report No. 18, edited by Deemer (17). In this report Alchian has written four chapters on the methods of statistical analysis employed in the AAF Aviation Psychology Program that are notable for their presentation of up-to-date concepts in surprisingly compact and straightforward fashion. The basic principles of modern statistical analysis and inference were stated succinctly (1, Chapter 20) and were followed by detailed descriptions of the procedures used to estimate the parameters of univariate distributions (1, Chapter 21). The statistics employed in bivariate analyses were set forth with the tests of significance appropriate for use with them (1, Chapter 22) and technics of multivariate analysis were described with special reference to regression statistics (1, Chapter 23).

This research report (No. 18) also includes two interesting chapters written by Simon and Berwick on machine technics. In one of these, detailed procedures for obtaining biserial correlation coefficients and intercorrelations were presented (96, Chapter 15), and in the other a method for obtaining the sums of squares and of products with the IBM alphabetical accounting machine was described (94).

Statistical procedures commonly used in one or two psychological research units for computing reliability coefficients, item-analysis data, validity data, and factorial data regarding items and tests were outlined by Humphreys (52, Chapter 3). The type of internal-consistency and external-criterion item-analysis data used in the development of the *Aviation Cadet Qualifying Examination* and many other examinations was explained by Davis (14, Appendix A). Detailed instructions for computing the data as well as evidence of its reliability were provided. Item difficulty indexes were found to be more reliably determined than item-test correlation coefficients. Guilford discussed the factorial composition of a large number of the tests developed for use in classifying aviation students and related these data to the criteria that were to be predicted (43, Chapter 28).

### Design of Equipment

The establishment of a Psychology Branch in the Aeromedical Laboratory at Wright Field, as reported by Fitts (24), provided a central point for psychological research on the design of equipment. Previously, considerable work in this area had been accomplished in the AAF Aviation Psychology Program, but no organization had been specifically charged

with the responsibility. A report edited by Fitts (23) presented the research data accumulated on the design of equipment with regard to human capabilities and limitations. The nature of engineering psychology and its applications, methods, and technics were discussed by Fitts (23, Chapter 1). Problems associated with the means of presenting information obtained in the form of instrument readings were described by Grether (40, Chapter 2). Brown and Jenkins prepared an outline of research related to the design of equipment, which was based on an analysis of human motor abilities (5). A bibliography was appended.

A number of studies have been made to determine how aircraft instruments and accessory materials should be designed to minimize errors in using them. Comparing the relative ease and accuracy with which tables and graphs were read, Carter concluded that tables are preferable as a means of presenting data if interpolation is not required. If it is, graphs are to be preferred (7, Chapter 4). The sources of error in reading air navigation plotters were identified and, according to Christensen (9), a new plotter has been designed that should prove considerably easier to use. Grether has shown that a twenty-four-hour dial face on a clock is easier to read than a twelve-hour dial face provided that time is to be read according to the twenty-four-hour system (40, Chapter 6). Optimum characteristics of a twenty-four-hour clock face were determined. Some findings with respect to dial faces are interesting; Grether and Williams discovered (40, Chapter 7) that the accuracy with which dials were read increased as their diameters were increased up to two inches. It also increased as gradations were increased to seven-tenths of an inch. On the other hand, speed of dial reading did not appear to be related to size of dial diameter or scale interval. A study of the interpretability of various types of aircraft attitude indicators, made by Loucks (68), showed that for blind flying the horizon should remain fixed and a three-dimensional miniature aircraft should constitute the moving element and should move in the direction in which the plane rolls.

Another group of related studies pertained to airplane control knobs and their uses. Weitz (108) concluded that coding control knobs by color and shape helped reduce the difficulty normally experienced when a pilot shifts to an unfamiliar airplane in which the controls are placed differently. Experimentation with control knobs of various shapes has indicated, according to Jenkins (54, Chapter 14), that knobs of certain shapes are less frequently confused than others and should be standardized for use in aircraft cockpits. Data obtained by Grether (40, Chapter 17) showed that airplane controls can be handled more efficiently with the arms and hands than with the legs and feet. Fore-and-aft movements were found more efficient than lateral movements. If a group of controls must be adjusted rapidly in a certain sequence, Murray recommended (78) that they be operated in a similar direction. Clockwise movement of a rotary control of an indicator should, Carter and Murray found (7, Chapter 10), be associated with downward and left-to-right movement of the indicator.

In a different experiment, Warrick discovered that clockwise rotation of a control knob should be associated with movement of an indicator toward the operator and from right to left (107, Chapter 9).

Mild anoxia (the condition resulting from lack of sufficient oxygen) seemed not to affect the number of illusions under experimental conditions reported by Grether, Cowles, and Jones (40, Chapter 19). The errors made by a pilot in reading instrument dials tends to increase in the presence of moderate *G* force, as indicated by Warrick, Nelson, and Lund (107, Chapter 20).

On the basis of an investigation of ability to reproduce pressures, Jenkins concluded (54, Chapter 12) that a wide range of pressures from five pounds up to thirty or forty pounds should be required in the operation of airplane controls. Pressures greater or less than those limits seem to be more difficult to reproduce accurately. According to Van Saun (104), for radar operators the polar-grid sector scope was superior to the cartesian-grid sector scope. Both scopes were more readily interpreted when the PPI scope and the sector scopes had the same orientation.

Important contributions were made by psychologists to the design of equipment for flexible gunners and to the technics used in sighting and aiming. Some of these have been mentioned previously in this chapter; others were discussed by Vallance (103, Chapter 14).

### Motion-Picture Testing and Research

A complete report of the work on motion-picture testing and research in the AAF Aviation Psychology Program was provided in the volume edited by Gibson (36). Some special aspects of the work have been mentioned previously in this chapter in connection with topics to which they are relevant; other aspects of the work will be summarized in this section.

The history, functions, and personnel of the Psychological Test Film Unit were first published in the *Psychological Bulletin* together with the hypotheses to be tested, research work under way, and test-construction technics employed (90). Gibson wrote more fully on these topics (36, Chapter 1). The peculiar characteristics of motion-picture tests and the unique possibilities of their application to psychological testing were discussed by Gagne, Bornemeier, Gibson, and Borin (32). Many practical problems in constructing and producing motion-picture tests were reported by Gibson, Bornemeier, Eisenberg, and Slater (36, Chapter 3). Some of the problems confronted in the presentation of motion-picture tests were mentioned by Finney and Gibson (21). Experimental evidence of the effects of varied amounts of illumination and of seating position on the perception of motion pictures was obtained. More theoretical were Gibson's discussion (36, Chapter 8) of the differences between the perception of pictures and the perception of visual realities and Gibson and Glaser's formulation (36, Chapter 9) of a systematic theory to account for observed data regarding individual ability in monocular space perception. Further research in the perception of space is needed, according to the authors.

### Implications of Psychological Research in the AAF Aviation Psychology Program

It has been impossible to include in this chapter all of the articles concerning the applications to psychological and educational research of work done in the AAF Aviation Psychology Program, but a great many references have been reviewed.

Flanagan discussed general contributions of the AAF Aviation Psychology Program to the theory and knowledge of individual differences and trait differences (25, Chapter 9). Considerations pertaining to the trait theory of human abilities, the measurement of traits, the significance of motivation, and the nature and significance of personality factors were taken up. Of special interest to educators was Flanagan's statement of the implications of research in aviation psychology regarding the nature and principles of learning, the relative importance of aptitude and training, and the measurement of success (25, Chapter 10). The procedures utilized in the AAF Aviation Psychology Program for the measurement of achievement and the prediction of human behavior will be of interest to research workers in psychology and education. Flanagan has discussed these along with the statistical technics and experimental methods employed (25, Chapter 12). He has also commented on several types of research studies leading to the design of equipment for maximum efficiency (25, Chapter 11). Altho to many research workers, much of the experimental work on the design of equipment may appear to be elaborate (and, therefore, expensive) demonstrations of the obvious, Flanagan believes that much work will be carried on in this field in the future. It would appear that this is likely, since its application in industrial psychology is clear.

Guilford has published considerable material concerning the general conclusions and implications drawn from testing and classifying aviation cadets in the AAF (43, Chapter 29). The discovery of aptitude and achievement variables was reported (42) and Guilford and Zimmerman (46) listed twenty-seven factors found by centroid analyses of a number of different correlation matrices based on scores from tests administered to highly selected men in aviation-cadet training. The factors have been identified subjectively by the authors and their co-workers in the AAF Aviation Psychology Program. In the case of ten of these factors the authors believe the names chosen for them may be reasonably accurate descriptions. The practical value of well-established psychological principles was demonstrated during the war, in the opinion of Guilford (43), who drew some lessons from aviation psychology. In another publication (44), Guilford mentioned findings that confirmed long-established principles of test theory; namely, that test validity coefficients are more important than test reliability coefficients for evaluating tests and that the value of a test for multiple selection should be judged in terms of its unique contribution to accuracy of prediction rather than in terms of its validity coefficient. There will be general agreement on these points, but whether factorial analysis pro-

vides the means of reaching the desired objectives may be a matter for further discussion among test technicians.

Davis prepared for a commission of the American Council on Education a brief description of the selection and classification procedures used in the armed forces together with their implications for civilian education (15). He indicated that the technics for selecting and classifying aviation cadets in the AAF Aviation Psychology Program constituted the first practical demonstration of the principles that are likely to form the basis for soundly conceived instruments useful in educational and vocational guidance in the future. For differential selection and classification of personnel it appears likely that tests will be developed to measure the variance common to the several criteria to be predicted and to measure separately the variance that is unique to each one of the criteria. The relative weighting of the tests measuring common and unique variance will depend on the proportion of the available manpower that can be rejected entirely. To secure measures of unique variance in each criterion it is not enough to make use of tests that are merely independent; in practice, such tests will probably be constructed by correlating individual test items (that measure as nearly as possible only one mental function and that are maximally reliable) with each one of the criteria to be predicted and building up groups of items that have correlations as high as possible with one criterion and as low as possible with all other criteria. This is the logical extension to test construction for purposes of differential classification of the principles employed to construct the *Aviation Cadet Qualifying Examination* for purposes of selection alone.

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- Chapter 19, "Experimental Apparatus Tests: 'Stress' Tests and Psychophysiological Tests"; Chapter 20, "Experimental Apparatus Tests: Miscellaneous Tests"; Chapter 21, "Special Research Projects: Selection of Flexible Gunners"; Chapter 22, "Special Research Projects: Selection of Radar Operators"; Chapter 23, "Special Research Projects: Selection of Bombardiers"; Chapter 24, "Special Research Projects: Psychomotor Performance Under Conditions of Anoxia and Drugs"; Chapter 25, "Summary of Evaluation." AAF Aviation Psychology Program Research Reports, No. 4. Washington, D. C.: U. S. Government Printing Office, 1948.
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## CHAPTER IV

### The Personnel Research Program of the Adjutant General's Office of the United States Army

E. DONALD SISSON

THE CONTRIBUTIONS of the Personnel Research Section of the Adjutant General's Office in World War II are reviewed in this chapter. This program was established in 1940 in the Adjutant General's Office with the advice of the Committee on Classification of Military Personnel of the National Research Council. This Committee, of which W. V. Bingham was chairman, included C. C. Brigham, H. E. Garrett, L. L. Thurstone, L. J. O'Rourke, M. W. Richardson, and C. L. Shartle.

The six main sections of this chapter present the work of the staff of the Adjutant General's Office on selection (I) and classification (II) procedures, training (III), the measurement of proficiency (IV), leadership (V), and tabulating and analysis technics (VI). Since the contributions of this group in the form of numbered pamphlets in the Personnel Research Section Report series are anonymous, the individuals who served on this staff from 1940 to 1946 are listed in the accompanying footnote.\*

\* Sidney Adams, Earl Alligaier, Jane M. Allison, Carl L. Anderson, Kenneth Ashcroft, Donald E. Baier, Melvin H. Baumhofer, Harold Bechtold, Roger M. Bellows, Albert H. Berg, Harold C. Bingham, Walter V. Bingham, Ruth Bishop, Reign H. Bittner, Edward S. Bordin, Hyman Brandt, Louis J. Braun, Robert E. Breden, Hubert E. Brodgen, Keith L. Broman, Emma E. Brown, Harry W. Bues, James W. Burns, James W. Campbell, Launor F. Carter, Frank C. Cassens, David J. Chesler, Charles L. Christiermin, Ruth D. Churchill, Kenneth E. Clark, Vernon E. Clark, Earl A. Cleveland, Charles W. Collins, Clyde H. Coombe, Herman A. Copeland, Horace H. Corbin, Robert E. L. Crane, G. Hamilton Crook, Edith Cummins, Edward E. Cureton, Manuel M. Cynamon, Karl M. Dallenbach, Tamara Danish, Jeanne C. Davis, D. M. Depew, Helen C. Dondy, Mitchell Dreese, Hilda F. Dunlap, Walter N. Durost, Robert F. Earhart, Jane L. Eastman, Marian B. Eller, Alvin C. Eurich, Solomon D. Evans, Dorothy W. Ewers, Ray Faulkner, Forrest Forcum, Fred C. Ford, Douglas H. Fryer, Richard H. Gaylord, John H. Glass, Eleanor W. Gluck, Norman I. Greenfield, Winslow Hallett, Wilfred Hamlin, Paul J. Hansen, Thomas W. Harrell, Wells Harrington, Edwin R. Henry, Betty B. Hemmelman, Charlotte G. Honig, Reuben Horchow, Reuben S. Horlick, Robert Iglesias, Mary C. Jarrett, Donald M. Johnson, Thornton C. Karlowski, Raymond A. Katzell, Walter Kelly, William M. Kephart, Philip M. Kitay, Richard Klamon, Celia M. Klinger, David R. Krathwohl, William C. Kvaraceus, Russell G. Leiter, Harry Leviton, Sidney Lind, Floyd H. Loquist, James M. Lynch, Grace E. Manson, Stanley C. Markey, Dorothy Mathis, Harold McAdoo, Gordon L. McDonald, Joseph L. Melcher, Marilyn R. Mendley, Gerard S. Napolitano, Belford B. Nelson, Philip Nogge, Margaret Norgaard, Bernice Orshansky, Joseph V. O'Rourke, Stanley W. Osgood, Charlotte M. Panimon, Richard H. Paynter, Ruth A. Pedersen (Miss), Edwin B. Petersen, Watson O. Pierce, Adam Poruban, Jr., Bronson Price, Barbara M. Quiat, Evelyn Raskin, Arthur E. Rasmussen, Mary K. Reddington, Prentis Reeves, Alexander B. Reid, Marion W. Richardson, Carmeline Roman, Edward A. Rundquist, James T. Russell, Willis C. Schaefer, William A. Schraeder, William J. Schulz, Janet B. Schwinger, John F. Scott, Robert B. Selover, William Shanner, James U. Shea, Winifred Shepler, Edward M. Sherbourne, Morton A. Siedenfeld, Meyer S. Siegel, Clement H. Sievers, Catherine Romano Sisson, E. Donald Sisson, Charles P. Sparks, Joseph L. Speicher, Naomi S. Stewart, Philip M. Stone, Ralph J. Strom, Margaret Strong, W. S. Studdiford, Calvin W. Taylor, E. K. Taylor, Helen D. Telford, James D. Teller, John T. Thomas, Robert M. W. Travers, Otis C. Trimble, Lillian E. Troll, Read D. Tuddenham, Harold S. Tuttle, Howard F. Uphoff, Arnold R. Verduin, Edgar G. Virene, Virginia W. Voeks, Florence S. Volkman, John L. Wallen, Arthur C. Ward, Robert J. Wherry, Miriam Whintrop, Lawrence Whisler, Carlton E. Wilder, Louis P. Willemin, John M. Willets, Nannie Mae Williams, William R. Wilson, Beryl B. Wisman, Louise R. Witmer, Kenneth Wood, Sarah Zakin, Edwin Ziegfeld, Ernest H. Ziegfeld.

## I. Selection

### Induction Standards

The differentiation of those who could learn to be proficient soldiers in a reasonable length of time from those of insufficient learning capacity for such service was a preliminary necessity in the utilization of manpower in the war effort. In order to distinguish enlistees who could learn duties of a soldier in the usual amount of time (*Army General Classification Test Grade III*) from slow learners (*Army General Classification Test Grade IV*), *Classification Test R-1* was developed (35) from *AGCT-1a* items with item-grade correlations of .35—.65. It was standardized (61) in June 1941. Critical scores equivalent to *AGCT* standard scores of ninety and one hundred were derived. Another form, *R-2*, was prepared from *AGCT-1b* in February 1942 (106), and similar critical scores established (119). Forms *R-3* and *R-4* were ready in May 1946 for use with men enlisting or reenlisting in the Army, and the relationship of these forms to *AGCT-3a* was studied (310). Placement and achievement tests in reading and arithmetic were constructed (254) for each of the four levels of training given in Special Training Units (STU) which were set up to teach illiterates possessing learning ability. Preliminary research was extensive; experimental forms were studied for item content, item-analyzed for difficulty, and validated. Standard score scales were constructed for these tests (250, 251).

*Literacy Tests.* Attempts were made to determine minimum literacy requirements for acceptance for induction, and to develop measures of mental capacity not dependent upon higher literacy levels. Minimum literacy tests were constructed early in 1941 to eliminate those unable to read at the fourth grade level. Critical scores were determined (56) using the *Metropolitan Advanced Reading Test*, Form A, as the reading ability criterion. *Minimum Literacy Test* (Form 1) scores of engineer trainees at Ft. Belvoir in August 1941 were studied in relation to ratings of unsatisfactory, satisfactory, and outstanding on fourteen criteria obtained from training records (55). A tetrachoric  $r$  of .45 between those passing and failing the test and the percent above and below the median training rating indicated some relationship between success on literacy test and success on "job." A sharp increase in the percent of unsatisfactory ratings below fourth-grade level indicated this minimum reading ability was a reasonable critical level. Two forms of a verbal measure of general learning ability, *Qualification Test Q-1* and *Qualification Test Q-2*, were released in June 1943, replacing the "pure literacy" test. Each test contained items on paragraph reading, arithmetic computation, and general orientation. Critical scores were established by which men were accepted, rejected, or assigned to special training. The percents of 3311 men tested in induction centers in three service commands scoring in the critical score intervals were tabulated (212, 242). The relationships of *Q-1* and other tests to

level of training in Special Training Units were studied (192) in September 1943.

*Nonverbal Group Mental Ability Tests.* *Visual Classification Tests VC-1, X-1; VC-1, X-2; VC-1, X-3; and VC-1a* were nonlanguage tests constructed to select a quota of illiterates with sufficient mental capacity to absorb army training. The item types included visual perception, paired comparison, and abstraction. Revised forms were developed from item analyses of the preceding forms (137, 157, 158, 160). *VC-1, X-2* was standardized on a population of 764 men containing Negroes and whites in a ratio of approximately five to one (138). A lower critical score was set to exclude the lowest 2 percent of the Army *GCT* population, an upper critical score corresponding to an *AGCT* standard score of sixty—Grade IV.

*Individual Tests of Mental Ability.* The *Wechsler Self-Administering Test* was found too difficult, with too narrow a range of scores among low-grade men. Study and item analysis (112) in March 1942 showed correlations of .83 with the *AGCT* for unrestricted range of 1250 men and .23 for restricted range of 375 low-grade (Grade V on *AGCT*) men. Its validity as a predictor of soldier performance ratings in Special Training Units was very low (218). Low correlations with these ratings of other Army induction tests (216), suggested the possible inadequacy of ratings.

*Over-All Studies.* In validation studies (test scores with ratings in Special Training Units) of groups of tests (209, 210, 211, 213), the tests with some verbal component were better than the others in screening the unsatisfactory STU men. Biserials between test scores and rejection after STU training or graduation ranged from .38 to .72 for the tests in use December 1943 to February 1944 (214). Various combinations of tests gave multiple correlations well above .60. *Qualification Test Q-1*, dependent to some extent upon literacy, was the best predictor. Standardization data (215) were obtained on three tentative test batteries. The results of the new induction program in June 1944 showed higher rejection rates than the old programs—approximately a 3.5 percent difference each month (242). Also, the educational inferiority of the southern selectee was evidenced by comparative rejection rates of Negroes and whites.

*Recruiting Standards for the Women's Army Corps (WAC).* Several mental alertness tests were developed for selecting women for the WAC. *Women's Classification Test WCT-1, X-2* (first designated *Mental Alertness Test MAT-1, X-2*), used in the selection of both enlisted women and officer candidates, was standardized (150) in 1942. The test had a Kuder-Richardson reliability of .94 and correlated highly with the *AGCT*, *Otis Group Intelligence*, *Otis Self-Administering*, and the *ACE* tests (150). A revised form, *WCT-2* used only to select enlistees had a Kuder-Richardson reliability of .97 and correlated .85 with the *AGCT* (199). It was standardized (202) on 12,000 applicants in October 1943. *WCT-2* was superior to the *AGCT* in predicting academic grades in WAC officer candidate school, but neither of the tests predicted leadership ratings (191). In 1944 a short recruiting test, *Classification Test R-1*, replaced *WCT-2*. *R-1*, which

has also been used for regular Army recruitment (v.s.) had a reliability of .94 and correlated .78 with WCT-2 (197).

### Selection for Specialist Training

A meteorology aptitude test was used by the Air Corps thru the war for the selection of weather observer students. This test battery, consisting of a mental alertness test of the traditional type and fifty meteorology and 144 physics true-false items, gave adequate validities and reliabilities (231). *Aircraft Warning Aptitude Test TC-10A* contained a section on locating grid points by coordinates and a section on plotting coordinates. The first part proved valid against the criterion of theoretical grades in courses, the second part against performance grades. *Aircraft Warning Classification Test TC-11a* was given to those who passed the previously mentioned test for classification into potential specialist categories. More than 90 percent of failures were eliminated (226). Among the specialized tests used in small, sometimes unsuccessful, programs to select trainees for highly specialized Army courses, were those for Balloon Barrage courses (129), Combat Intelligence courses (181, 196), Military Police courses (171), and Medical Technicians (162). A battery including the *AGCT* and several mechanical aptitude tests was investigated for use to select Air Corps bombardiers and navigators. Paper-and-pencil tests were found to be related (73) to academic course grades but not to flight-training records. However, reliability of the latter criterion was low. Research in this area was subsequently transferred to the Air Surgeon's Office in December 1941. A large-scale comparative study of apparatus and written tests was conducted for the purpose of validating and standardizing an aptitude testing program for Air Corps basic-training centers. The written tests were generally superior to the apparatus tests against the criterion of academic success in training courses (227, 228, 229). Tests finally chosen for the battery contained only two performance tests out of a large number tried: (a) *Nut and Bolt Manual Dexterity Test TC-5a*, and (b) *U-Bolt Assembly Test TC-6a*. An attempt was made to validate the instruments against on-the-job performance as judged by five types of supervisory ratings of Air Force ground-crew men in active units. The written tests showed lower validity than with the criterion of academic success. All validities were much lower than in unselected, untrained populations (290, 291). The *U-Bolt Assembly Test* appeared to be of some promise. Tests of informal information in shop mechanics, automotive and driver information, electricity, and radio, originally intended for use together with the latest form of the *AGCT* to form a comprehensive basic classification battery in initial processing, have instead been adopted for use at training centers to select men for specialized training. Two forms of the *Automotive Information Test* (*AI-1* and *2*) and of the *Shop Mechanics Test* (*SM-1* and *2*) have been standardized on large populations (252). Extensive item analyses and validity studies of all four tests have

also been conducted (228, 236, 280, 281, 282, 283, 284), with adequate validities obtained. A preference record and a self-description form based on the forced-choice technic were validated against a production index and a 3-point rating in a study of selection instruments for personnel suitable for recruiting work (289), with disappointing results.

*Radio Code Operators.* Investigations by the Personnel Research Section and various other agencies have resulted in the authorization for Army-wide use of two tests for selecting radio code operator trainees. Many other code aptitude tests have been considered. The criteria used for the validities reported here include number of hours to reach specified receiving speeds, final code speed attained, and the NDRC *Code Receiving Tests*. Usually, several of these were considered in each study (15). The *Signal Corps Code Aptitude Test (SCCA)* evolved from a test tried out by the Signal Corps between 1924 and 1931. By 1941 the *SCCA* was widely used by several of the Arms and Services. Usually administered by phonographic transcriptions, the *SCCA* was a code discrimination type test containing seventy-eight pairs of patterns to be identified as "same" or "different." Reliability estimates by Kuder-Richardson Formula No. 21 were much lower than desirable, ranging from .67 to .78, except for one sample for which .88 was reported (60, 91, 140, 184, 195). Validity data varied considerably from one sample to another, with coefficients from -.03 to .57 (18, 60, 83, 92, 139). Data reported by the Signal Corps for testing between the wars gave validities ranging from .54 to .75 (105). Little improvement in reliability or validity resulted from doubling the *SCCA* to make the *Radiotelegraph Operator Aptitude Test ROA-1, X-1*, which was authorized for Army-wide reception center use in July 1942. The Kuder-Richardson reliability was .87 and reliabilities by the split-half method ranged from .73 to .82 (146, 184, 195). Validity of *ROA-1, X-1* was only fair, usually around .30 (161, 186, 195, 224). The test was standardized on the basis of *SCCA* results, standard scores being set to a mean of 100 and a sigma of 20 (102). Studies indicated that previous musical instrument experience as well as code experience were positively related to radio code test scores and added to success in radio code training (60, 184). Data from numerous radio operator specialist schools indicate that fewer failures result if men are preselected on *ROA-1, X-1* plus *AGCT* rather than *AGCT* alone (224). *Army Radio Code Aptitude Test, ARC-1*, a code learning test developed by The National Defense Research Council (18) took the place of *ROA-1, X-1* toward the end of 1944. The test required the recognition of three learned Morse Code letters when presented with unlearned characters. Validities for *ARC-1*, usually between .50 and .60, were higher than those for *ROA-1, X-1* or the *Thurstone Code Aptitude Test* (224). A check on the standardization sample resulted in the raising of raw score equivalents for the various standard scores (248). A series of *Code Learning Tests*, work-sample tests based on the same principle as *ARC-1*, showed considerable promise but were never carried to the completion stage. Reliabilities by Kuder-Richardson Formula No. 21 and by estimation from odd-even

correlations ranging from .94 to .98 have resulted for various editions of the test (65, 91, 128, 140, 161). Validities have, in general, been as good as for either the *ROA-1, X-1* or *ARC-1* (65, 140). A paper-and-pencil alphabet-symbol *Substitution Test-1, X-1*, also developed by the Personnel Research Section, gave reliabilities over .95 but was somewhat less valid than *ROA-1, X-1* (128, 140, 161). A revised edition of a *Code Rhythm Test* developed by Thurstone has also shown some promise (105, 128). The *Thurstone Code Aptitude Test* was tried out in studies on *ARC-1* and a revision of this test, designated *ROA-2, X-1*, was accomplished (205). Both tests were highly reliable but the original Thurstone test was more valid.

**Truck Drivers.** Research resulted in the standardization and validation of a group of tests (16), including a *Driver Experience Inventory*, a *Driver Information Test*, tests of visual acuity and night vision, and a reaction-time test. Other well-known psychophysical tests were assessed as predictors of driving ability. Most frequent criterion was a road test, consisting of fifteen to twenty minutes observation of driver in the standardized situation. Specific tests were checked on a *Road Test Check List*. A score consisting of checks of correct or incorrect operations, weighted or unweighted was obtained, plus an over-all rating. Reliability coefficients for the road test were not as high as those usually obtained for objective tests, but equalled those usually obtained for criteria in validity studies (24, 64, 72, 86, 126). Two forms of a *Driver Information Test (DIT)* were standardized (172, 176). Trial of personal history items showed driving experience items to be most valid (25, 72, 123, 134, 152). A *Driver Experience Inventory* showed variable validity, fairly high in certain populations (120, 147, 172).

**Visual Acuity.** Several of the more familiar visual acuity tests gave consistently low correlations with the road test (25, 72, 126). Tests of night vision gave higher validities against a special night road test (71, 76, 131). Studies of race differences in night vision (25, 78, 121) produced no consistent or significant results. High sugar intake showed no effect on night vision (72). Studies are currently in progress on the standardization of new tests of visual acuity and night vision.

**Sensori-Motor Tests.** Data show low positive and zero correlations and some inconsistency from sample to sample in studies of several sensori-motor tests as predictors of ratings of driving ability. However, populations were often small and criteria not always reliable. In addition, soldiers are already a physically selected population (25, 71, 126).

### Trade Knowledge Tests

Numerous editions of tests in electricity, radio, and automotive mechanics have been developed to aid in the identification of those with interests and aptitudes in these fields, as evidenced by possession of informal information. A *General Electrical and Radio Information Test* was constructed after item analysis of experimental forms (100). Subsequently, separate

series in electricity and in radio were established. Limited analysis revealed some fair validities (227, 239). A *General Automotive Information Test* yielded a correlation of .67 with course grades of 147 men (110). The test was further expanded and item analyses and additional validity studies were carried out (122, 142, 169, 183, 239).

### West Point Qualifying Examinations

Each year since 1942 a new form of *West Point Qualifying Examination (WPQ)* has been constructed for administration along with the regular West Point examinations. It is intended that this battery eventually replace present West Point entrance examinations. The latest form of the *WPQ* contains two subtests, *Language Aptitude* (learning an artificial language), and *Elementary Mathematics* (the use of short-cuts in arithmetical and algebraic processes). Each year's series was tried experimentally and prevalidated on classes already selected and attending the Academy and administered in final form to applicants the following year. Additional validity data were gathered subsequently, with academic success as criterion (164, 174, 182, 190, 219, 220).

### Selection of Warrant Officers

Objective examinations have been developed in over thirty administrative and technical military specialties for the selection of warrant officers. The subjects range from Auditing and Accounting to Weather and Cryptography. No reliability or validity data have been gathered on these tests, altho they were constructed with the aid of technical experts and have been widely used (237, 275, 276).

### Personality Studies

In 1942, Personnel Form P-1, also known as the *Shipley Personality Inventory*, was proposed as a group test for military use in differentiating troublemakers, neurotics, and normals. Extreme troublemakers and extreme neurotics were identified by this instrument (149), but reliability (136) was very low. More intensive research in personality measurement by the Personnel Research Section was begun toward the end of 1943. The *Minnesota Multiphasic Personality Inventory*, adapted and revised for Army use, the *Cornell Selectee Index*, the *Army Individual Test* (See Chapter II), and the *Biographical Information Blank* (See Chapter VI) were among the instruments studied (61). The *Multiphasic Personality Inventory*, a paper-and-pencil objective test, scored separately for each of nine psychiatric classifications, showed promise; its items were analyzed and some selected (294) for inclusion in the *Biographical Information Blank* used in the regular army officer retention program (See Chapter II). Validity studies of the *Multiphasic Inventory* were made in connec-

tion with predicting AWOL's and psychiatric referrals among basic trainees, predicting psychiatric rejects among WAC applicants, selecting trainees for Arctic duty, and validating against careful psychiatric diagnoses. Results have been favorable enough to justify further study and development of the inventory. An item analysis of responses of "good" and "bad" WAC applicants did not show significant differences (314). Correlational analyses of the *Army Individual Test*, composed of six separate subtests and administered to a population of psychoneurotics and psychotics, suggested the validity of the *AIT* for differentiating between psychoneurotics and specific psychiatric diagnostic categories, particularly when products and squares of test scores, rather than sums and differences, were used (313). The Army Wechsler subtest scores were found to add little to predictions.

## II. Classification

### The Army General Classification Test

The *Army General Classification Test* (3, 7), providing an index of the learning ability of recruits to facilitate classification for training and job assignment, was first released as *AGCT-1a* in October 1940. Subsequent forms, including two Spanish versions (258), were issued during the war; *AGCT-1b* in April 1941; *1c* and *1d* in October 1941. These consisted of 140 to 150 multiple-choice items on vocabulary, arithmetic, and block counting. Raw scores were converted to standard scores with a mean of 100 and a standard deviation of 20. Standard scores were divided into five Army Grades. A revised series, in which part scores were recorded for the first time, appeared as *AGCT-3a* in April 1945 and *AGCT-3b* in 1946 (236, 278). The *AGCT-3* series contained four tests: reading and vocabulary (189), arithmetic computation, arithmetic reasoning (235), and pattern analysis. The total score was the equivalent of the *AGCT-1* score while part scores were also used in classification. An information battery, originally intended for inclusion in the *AGCT-3*, was used instead for classification purposes at training centers. Four forms of each type of subtest in the *AGCT-3* were developed and equated for content and difficulty.

*Standardization.* Standardization of *Form 1a* (31) was accomplished, before the first inductees under the Selective Service Act entered the Army, on a population of regular Army and CCC men equated to the expected Army population by weighting on age, education, and area of residence. Due to several other factors which could not be taken into account, e.g., race, occupational deferments, illiteracy, direct commissions, the distribution curve of the actual Army population varied from the expected. Despite this variance, the conversion table for *Form 1b* (40) was computed by combination regression of *1a* and *1b* scores, because the norms for *1a* were already widely used for classification. Standardization of *Forms 1c* and *1d* (42) was based on *1a* and *1b*. Distributions on *Forms 1c* and *1d* had less negative skewness, and the conversion tables were set up to yield

Army grade percent midway between the old and the new forms. Improved discrimination of *1c* and *1d* was partly due to more equitable distribution of item difficulty. *Form 3a* was standardized (236) on a population of 39,000, carefully stratified and weighted by age, education, race, and geographical location.

*Item Analyses.* Studies of response frequencies, item difficulty, discriminating power, and item-test consistency (29, 30, 35, 41, 115) were used for guidance in construction of alternate forms. It was found that equal scores might represent widely differing performances in type of questions answered (143, 117). Most extensive item analyses were made on the four trial forms for the *AGCT-3* (236). Final form items were carefully graduated in difficulty and selected on the basis of item-total test correlation.

*Practice Effect.* Study of practice effect on *1a* and *1b* scores (39) and *1c* and *1d* scores (42) showed small but consistent increases regardless of which form was taken first. Retesting after considerable lapse of time for Grade V men (173) and men in OCS (163) showed similar results, which were attributable to factors other than the effects of Army training.

*Part Scores.* Altho part scores of the *AGCT-1* were not used for classification, investigation was made of relative contributions, discriminative power, intercorrelation, reliability of parts, and correlations with part and total scores of other forms (36, 38, 114). Each part was found to make a significant contribution. Combined vocabulary and arithmetic scores of one form were found as good as total scores for predicting total scores on a second form.

*Reliability.* Repeated reliability estimates on all forms by Kuder-Richardson Formula No. 21 (31, 40, 42, 236), odd-even comparisons (31), retest (75), alternate forms (38, 42, 236), and Kuder-Richardson Formula No. 2 (236) placed the reliability generally above .90.

*Validation.* Several hundred validity coefficients attest to the value of the *AGCT* in selecting men for a large number of Army specialist courses (27, 37, 57, 68, 73, 77, 89, 92, 94, 97, 99, 108, 113, 129, 132, 174, 175, 176, 178, 201, 213, 223, 226, 277, 324, 336, 338). Most of the populations were preselected either on the *AGCT* or on some highly correlated factor. The criterion was usually academic grades. Where preselection was rigorous, correlations were lower. Validities for criteria involving personality, e.g., success in Officer Candidate School (99, 132, 175, 198), or formal academic background, e.g., success in the Army Specialized Training Program (324, 336, 338), are low. *AGCT-3a* (227) was generally superior to *AGCT-1*. The reading and vocabulary subtest correlates highest with written examinations, and pattern analysis is usually the best predictor of practical performance. Use of part or combined subscores in classification is questionable because of high subscore intercorrelations.

*Relationship with Other Variables.* Studies show high correlation with education (31, 118, 127, 136, 270) and with other well-known tests of mental ability (32, 34, 103, 104, 165, 257, 331), decreasing with restric-

tive preselection, but no significant relationship with age (31, 118, 236), except that in highly selected groups, correlations tended to be slightly negative. Comparisons of male and female Army populations in age, cultural and educational background, selection methods, and geographical distribution, had inconclusive results (236). Comparisons of Negroes and whites (117, 270), complicated by social, cultural, and educational differences, showed lower mean scores for Negroes, the difference decreasing where educational status was matched. Mean scores for northern soldiers of both races are higher than for southern soldiers of the corresponding race. An early tentative study of relationship to civilian and military occupations (26) was made. Later studies showed a definite occupational hierarchy and sectional differences within occupations (270), despite considerable overlap, even between highest and lowest ranks; but no relationship to age or experience was found. Variability of scores was higher in lower level occupations. Occupations with restricted score ranges probably depend on abilities measured by *AGCT*; others with wider ranges depend more on specific interests or aptitudes. For counseling purposes a low score was considered possible ground for avoiding a high level occupation, but a high score *per se* is no ground for avoiding any occupation.

*Special General Classification Tests.* A special *Non-Language Test 2abc* to test illiterates and Grade V men was standardized (59) on a population with a normal distribution of *AGCT* scores. An *Army Individual Test (AIT)* of general mental ability (16, 17) consisting of three verbal and three performance tests (221, 222) was standardized (230) on a group of 1000 native-born literate whites. A study on a small population (222) indicated that the test could discriminate between Grade V men in Special Training Units who were likely to succeed or likely to fail in Army training.

### The Mechanical Aptitude Test (MAT)

The general *Mechanical Aptitude Test MA-1* appeared in February 1941. *Forms MA-2 and MA-3* were released in October 1941. A later form, *MA-4, X-1*, was built for WACs. *MA-1* consisted of items on mechanical movements (54), surface development, and shop mathematics. *MA-2* and *MA-3* differed considerably from *MA-1*, containing mechanical information (23, 53), mechanical comprehension (51, 50), and surface development; of which the first two were found to be good predictors for mechanics courses (58). *MA-4, X-1* contained items on tool recognition, mechanical comprehension, and surface development. Use of the *MAT* at reception centers, where scores were recorded for all except illiterates and Grade V men on the *AGCT*, continued until April 1945. It was supplanted by the *AGCT-3a*, which contains a surface development section similar to the *MAT*. Thereafter the *MAT* was used whenever deemed advisable at training centers.

*Standardization.* *MA-1* was standardized on 3452 men (47). Standard

scores, with a mean of 100 and a sigma of .20, were calculated by equivalent percentiles yielding a breakdown in five Army grades which approximated a normal distribution. *MA-2* and *-3*, based on item analysis of trial forms (70, 82), were standardized (90) by equivalent percentiles for *MA-1* scores on a population of 2766 men. *MA-4*, *X-1* was standardized by linear transformation (154), and was item analyzed (180).

**Reliability.** Estimates by the Kuder-Richardson Formula No. 21 (46, 47, 90, 154), test-retest method (49, 163), and equivalent forms method (90) show satisfactory reliabilities for both total scores and subtests.

**Validity.** Validity studies gathered a wide range of correlations, usually lowered by preselection, with course grades and other criteria. As a verbal test, the *MAT* correlates best with theoretical course grades (66, 227) and motor mechanics (48, 49, 89, 97, 103, 125); less well with driver performance ratings (156, 172); and negligibly with radio code receiving speed (84, 201, 205). Varying results were obtained for clerks (94), aircraft warning operators (226), airplane mechanics (194, 201, 228, 229), basic trainees (68), and Navy trainees (52, 129). Validity of *MA-4*, *X-1* with WAC specialist school grades as criteria (186) was superior to the *AGCT* for motor transport, but inferior for radio repair school. A study of *MA-4*, *X-1* for civilian armament trainees (239) found that its validity would be improved if the *Surface Development Subtest* were omitted.

**Relationship to Subtests and Other Tests.** *MA-2* and *MA-3* were found to be superior to *MA-1* in being less highly correlated with the *AGCT* (47, 69, 87, 90, 95, 96, 226). Intercorrelations of total scores and subtests were high (47). Correlations were computed for the *MAT* and civilian mechanical aptitude tests (49, 52, 226, 227).

**Tests of Mechanical Aptitude for Civilians.** A provisional battery, *Mechanical Aptitude Test MA-5*, was not as valid as standard civilian mechanical tests (250). A mechanical aptitude battery consisting of *Learning Ability Test LA-5* (an Air Corps test of mental ability), *Tool Usage*, *Mechanical Problems*, and *Paper Form Board Test CG-106a* did distinguish mechanics from nonmechanical workers (260). *General Mechanical Aptitude Test CM-142a* yielded fair correlations with both final mechanical grades and supervisors' ratings (263). A revision of this test, made shortly after V-J day, was designated *CM-142ar* (264).

### Clerical Aptitude

**Clerical Aptitude Test CA-1**, completed in 1940, consists of 280 items on name checking, coding, catalog numbers, verbal reasoning, number checking, and vocabulary. It was standardized (20) on a group normally distributed by *AGCT* scores. Resulting distribution (63) was leptokurtic for both the standardization sample and field returns. Reliability by Kuder-Richardson Formula No. 21 was .95 (20), by test-retest method .72 (163). Validity coefficients are usually based on small populations, the criterion being clerical school grades (19, 47, 69, 94, 96). Since it is highly corre-

lated with the *AGCT* (21, 47, 69, 94, 96) and sometimes inferior as a predictor of clerical grades to the *AGCT*, the *Mechanical Aptitude Test* (94), or the Wells Revision of the Army Alpha (19) its usefulness has been questioned. Experimental material for an uncompleted alternate form of *CA-1* was used in constructing *Clerical Aptitude Test CA-2, X-2* for the WAC, which covered classifying, cataloging, number and name checking, alphabetizing, and spelling. In the standardization the score distribution departed markedly from the normal, and the percentile method was used to set up standard score scales. The Kuder-Richardson reliability was .97 (154, 179). Validity studies (186) with grades in specialist courses as criteria showed *CA-2, X-2* to be inferior to the *AGCT* for administrative specialists. More widely used than any of the above clerical aptitude tests were those developed for civilian employees of the War Department, which in chronological order of use were the *General Proficiency Test WCT-1, X-3* (151, 155); *CA-2, X-2* (179, 185); a provisional battery, *Clerical Aptitude Test CA-3* (261); and finally *General Clerical Abilities Test CC-105a* (241, 247, 262, 292). Part A of *CA-3* correlated .32 with supervisors' ratings in some jobs (233, 240). Parts of *CC-105a* had an average correlation of .35 with Civil Service CAF grade and supervisors' ratings, but in a number of cases reached correlations around .50 (259, 293, 317).

### Army Trade Screening Tests

To verify skill status in Military Occupational Specialties a series of *Army Trade Screening Tests* and *Experience Check Lists* in clerical, mechanical, and other technical fields was developed (10, 286, 287, 288). Reliabilities, estimated by Kuder-Richardson Formula No. 4 for eight of the tests, ranged from .87 to .93. Critical scores were set for most of the tests to represent the level of technical achievement attained by graduates of the corresponding Army specialist course. Critical ratios between experienced and inexperienced men were high. Critical ratios dropped when examinees were encouraged to guess.

## III. Training

### Measurement of Academic Knowledge

Measures of educational achievement in the armed forces gained a new importance with the inauguration of the Army Specialized Training Program. Tests in academic subjects such as Algebra, English, etc. were constructed for the Air Forces (67, 87, 93), Corps of Engineers (68, 116), Coast Artillery (142), and the WAC (170). These tests were used as early selection devices until instruments of better validity were developed. A study was also conducted on the difficulty level and usefulness of a *General Educational Test* for Warrant Officer candidates constructed by the Cooperative Test Service (249).

*The Army Specialized Training Program: Selection Tests.* At the inception of the Army Specialized Training Program (8) a test constructed for officer candidate selection, the *OCT-2, X-3*, was found useful as a general ability test (318, 319). It was a considerably better predictor of success in basic engineering courses than the *AGCT* (324, 334). For the Army Specialized Training Reserve Program, three *Army-Navy Qualifying Examinations* were constructed by the College Entrance Board for screening applicants (320, 323, 331). A qualifying test (*C-4*), composed of mathematics and vocabulary items, was prepared by the Personnel Research Section for the same purpose, and was found to discriminate satisfactorily (341) among applicants. A *Mathematics Inventory Test*, from which the mathematics section of *C-4* was derived, was used for placement in appropriate curriculums, at the proper level of difficulty, and proved to be a good predictor of success in the *ASTRP* (340). A series of aptitude tests for professional medical training was also built (328, 329) and their relationship to *AGCT* (325, 326) and other educational factors (330) was studied. Certain achievement tests in mathematics and physics were used as selection devices for some advanced courses.

*Achievement Tests.* More than 150 different national achievement tests covering at least eight subjectmatter fields (6) were administered in all basic and advanced courses as a check on uniformity of content and adequacy of instruction given in approximately 200 different training units. These included tests for seven different foreign languages. A series of studies recorded reliabilities for the tests (6). Attempts were made to develop valid norms for test scores (322, 332). Item analyses on preliminary forms (327, 337) aided in constructing more reliable forms of the tests. The validity of the tests as predictors of success in basic engineering was investigated (321). Studies of correlations between  $R$  and  $R - \frac{1}{3}W$  showed that guessing had little effect on test reliability (333, 335). A socio-economic study (339) determined that 30 percent of the trainees were receiving more education than their prewar plans contemplated. One result of the national achievement testing program was that many instructors who originally opposed objective testing in college courses came to accept its value.

### Military Training

A *Military Knowledge Test* consisting of multiple-choice items and organized in pictorial form throughout was developed to test the basic military knowledge required of all soldiers. This test evolved from an item analysis of several experimental forms. It was used as a device to determine whether men being redeployed needed refresher training. The test distinguished trained and untrained infantrymen; however, validities were around .30 against the *Soldier Performance Scale* (See Chapter IV).

*Army Automotive Screening Battery. An Experience Check List, and Apprentice Mechanics Test, a Tool Usage Film Strip Test, and Distributor*

*and Valves Assembly and Use of Tools performance tests, administered by the "successive hurdle" method, have been used with great success to screen army automotive students who could bypass elementary phases of training.* Based on trial of many experimental forms and methods of scoring, the battery showed high validity (255). A subsequent follow-up study showed that students selected to skip beginning phases of training on the basis of these tests completed the course even more successfully than students taking the entire course (256).

#### IV. Measures of Proficiency and Criteria

##### Truck Driving and Machine Shop Performance

Performance criteria for truck driver trainees consisted of a practical road test checklist with objective ratings on specific items and a general driving proficiency rating, usually on a 5-point scale. The reliabilities of road test ratings are as high as those usually available for practical performance criteria. An early attempt at extreme objectification (64) was abandoned because of poor results. In one study the biserial correlation between number of unsatisfactory items on a checklist and general ratings was .83 for 1982 men and .28 for 1454 men rated under somewhat different conditions (72). Weighted checklist scores had tetrachoric correlations between .51 and .82 with general ratings for a sample of 1717 men (86). Other reliabilities are recorded using the split-half method (126) and test-retest method (24) on checklist scores. The general conclusion was drawn that reliability can be increased by training the examiners.

Three raters were used to rate examinees on performance on a list of common machine shop operations. Estimated agreement among raters was fair. Average reliability of all three raters was .80 (107).

##### Soldier Performance Report

Major use of the *Soldier Performance Report* was as a criterion for predictor tests such as the *Army General Classification Test* and the *Army Individual Test* in an effort to screen potential satisfactory soldiers from poor risks before basic training. Two early experiments (98, 203) were reported. Another study, validating a group of induction station tests (208), used a scale restricted to marginally satisfactory and unsatisfactory ratings. Contingency coefficients of reliability ranged (corrected) between .64 and .78. Somewhat lower coefficients were obtained for a much more restricted group on *AGCT* scores (211). In the validation of induction station tests an 8-point scale and a composite checklist were used (210). To validate a military knowledge test, a soldier performance scale (279), in which a superior noncommissioned officer rated the soldier on a 5-point description scale, showed satisfactory reliability (above .80) by rating and rerating comparisons and correlations between ratings by platoon leaders and platoon sergeants.

### AAF Technical School Success

Attempts were made to find criteria more reliable than academic course grades for predictors of success in AAF schools. Paired comparisons (229) showed high reliability for small groups of ratees. Closest approximation to on-the-job conditions was tried (290) on technicians in AAF combat units in the ZI. Five types of on-the-job rating were secured: rank in over-all job ability, paired comparisons, and a five-step scale on performance, personality, and over-all worth. Odd-even reliabilities were high except for personality. Intercorrelations were about .90.

### War Department Civilian Employees

Dissatisfaction with the reliability of criteria in use for test predictors in clerical work led to some experimental work on supervisory ratings. Two ability rating scales and a trait scale were constructed (293). They showed less correlation with predictor test grades than did civil service grade.

### Officer Efficiency

A criterion originally developed to validate devices for measuring leadership and personality fitness among officers became the backbone of several programs of officer selection, retention, and efficiency reporting. The adequacy of the criterion depends on the agreement of groups of officers intimately acquainted with the character and proficiency of given officers as to their placement in widely separated positions along a continuum of over-all competence (343). It was determined that a random group of ten rating officers can distinguish the over-all competence of officers almost as well as can a designated group of ten selected raters. In order that assignment to any criterion group be reliable, the officer being rated should be known well enough to be rated by at least seven out of ten raters. This procedure was perfected in the "Buddy Rating System" (295, 297) in an experiment with Officer Candidate School classes. Pooled independent ratings by a group of "buddies," when checked against ratings by the platoon officer, yielded a highly reliable criterion against which to measure selection instruments. The corrected split-half reliability varied between .81 and .91, and correlations between buddy and platoon officer ratings ranged from .51 to .59. Greater reliability (295) was obtained as length of acquaintanceship increased. A system was devised for assigning a criterion index score of from 0 to 60 to include, in addition to definite criterion groups of high, middle, and low competence, those men of more indeterminate status (298). A variant of the original pooled rating system, comparison of the officer with Army Officers in general and with officers of the same grade on a 20-point scale, was later developed and showed high correlation with the criterion index (266).

## V. Studies of Leadership

### Officer Selection

Tests, rating forms, officer evaluation reports, interviewing procedures, and other devices were developed and investigated for measuring background, learning ability, and leadership qualities of officers and officer candidates. In 1941 two forms of the *Higher Examination*, *H-1* and *H-2*, containing the most difficult vocabulary and arithmetic items, were constructed. These forms were intended for more exact discrimination among candidates in Army Grades I and II on the *AGCT*. Tables of equivalent scores with the *AGCT* were prepared (74). Both forms correlate highly with each other and with the *AGCT*. Reliability coefficients are high. Undue emphasis on speed caused examinations to be discontinued for officer candidate selection because the speed factor appeared to discriminate against the older men. *Form H-1* correlated .48 with final grades for sixty-seven engineer officer candidates (79, 85, 88). *War Orientation Test*, *WOT-1*, *X-1*, containing 100 five-alternative items on information about current events, had high reliability and gave significant differences in means between officer candidates and basic trainees, but had lower validity than the *AGCT* as a predictor of success at Officer Candidate School (153).

*Officer Candidate Tests*, *OCT-1* and *OCT-2*. Experimental forms contained items on comprehension of paragraphs and graphic material and on arithmetic reasoning, which were chosen from the *Army Officers Training Examination*, a battery developed for the War Department by the Co-operative Test Service. Reliabilities for the first experimental form were not satisfactory but higher correlations with OCS grades were obtained than for the *AGCT* (148). Conversion tables to *AGCT* scores were prepared and an item analysis made (118, 167). The test was rejected because informational content was taken from commonly used War Department manuals. Two final forms, *OCT-1* and *OCT-2*, were constructed after item analysis of two new experimental forms (168) and standardized on 2000 men (175). Reliabilities were .81 and .91 respectively by the Kuder-Richardson Formula No. 21. Both forms correlated highly with the *AGCT* and with years of education in an unselected population. Validity coefficients were high, both tests being far superior to the *AGCT* as predictors of academic success in Officer Candidate School (198).

*Leadership Studies*. Early approaches were based on analysis of War Department and civilian literature on leadership, management, etc. Two rating scales were developed but not validated. Interview procedures and forms were also developed and analyzed (177). Projective technics were investigated by the administration of the *Rorschach* and *Thematic Apperception Tests*, sentence absurdities, picture absurdities, and *Philo-Phobe* list to fifty-two men. Most correlations with leadership ratings were low. Practical difficulties precluded the use of these instruments on a large scale (177). *Preference Inventory*, *PL-1*, *X-1* contained 100 groups of three activities, each presumably preferred by the combat leader, administrative

leader, or the nonleader. Correlation with leadership ratings at OCS were insignificant (204). *Leadership Test, L-1, X-1*, requiring judgment in leadership situations, was also discarded (178). Combat reports from the North African campaign and analysis of leadership selection by British and German armies and of civilian research in the United States led to reexamination of leadership selection methods. Suggestions were made by the subcommittee on leadership of the American Psychological Association Emergency Committee on Psychology. Ernest Ligon, Consultant to the Secretary of War, reported on lack of uniformity in current officer selection procedures. A *Combat Adaptability Rating Scale* was used in conjunction with a series of tests including an interview, performance situation, and stress situations. Reliability of ratings was high, but low correlations were obtained between the rating scale and tests (225). No follow-up studies were made of individuals in actual combat because of administrative difficulties.

*Officer Retention Program.* The largest, most successful, and most revolutionary program in leader selection was worked out for the program of selection from among temporary officers of those to be given permanent commissions and integrated into the postwar regular Army (4). Personnel instruments developed include an *Officer's Application for Commission*; an *Officer Classification Test, OCT-14*, a test of general learning ability of suitable reliability but not adopted for other reasons; a *General Survey Test* of general educational achievement, including material from the fields of English usage, humanities, physical and biological sciences, and social sciences; a *Biographical Information Blank*; an *Officer Evaluation Report*, an improved efficiency rating device; and a *Standard Interview Procedure*, a new type board interview which was objective, reliable, uniform, and completely different from usual Army board proceedings. The *General Survey Test* is used as an initial hurdle, while scores on the *Biographical Information Blank*, *Officer Evaluation Report*, and *Interview* are combined to yield a composite score indicating over-all fitness. All instruments have been shown to be valid for representative officer samples against rigid criteria of agreement by fellow officers as to each applicant's over-all fitness (13). A general bibliography on leadership was compiled as background for the program (9).

*Construction of Selection Instruments.* Preliminary forms were tried out on approximately 8000 officers and officer candidates. Two 125-item forms of the *Officer Classification Test (OCT)*, containing sections on reading comprehension, arithmetic reasoning, and interpretation and judgment, were each administered to groups of 500 officers. Two final 110-item forms were constructed on the basis of item analysis (306). A study of equivalence showed appreciable difference between forms (305). *Form A* had good validity for predicting success in technical courses (307), but did not correlate with general criterion of officer competence used in major study (see *Validity of Battery*, below). *Form 1* of the *General Survey Test (GST)* contained 200 items selected from two preliminary forms after item analysis of 1000 cases (306). Percents of applicants selected by various cut-off

scores by Army and Service and educational level were determined (311). The *Biographical Information Blank (BIB)* (297) provided a means for objectively measuring elements of past experience and personal characteristics, experimentally determined to be significant for predicting officer success. *Form E*, the final form used, contained 204 items divided into four parts: eighty-two biographical items, twelve pairs of self-evaluation items, ninety-four officer description items in forty-seven groups, and sixteen multiphasic pairs of items. All technics of personality measurement which had shown promise were investigated and the "forced-choice" technic exploited. Nine types of items received preliminary trial. Self-description items were presented in quintets (295) containing two desirable, two undesirable, and one neutral alternative. The two desirable or undesirable characteristics were equal with respect to degree of desirability, but differed as to relative importance for officer success. Scale values had been obtained previously (296). One hundred ten pairs of items from the *Minnesota Multiphasic Inventory, Form TC-8a*, were tried (294). The criterion for item selection on the *BIB* consisted of "buddy ratings" by fellow officer candidates and a ranking by platoon officers. Reliability of the "buddy ratings" was high. Correlations of ratings with the *AGCT* and education is low, consistent with other studies. Alternatives were then analyzed as to correlations with high or low criterion groups of officers. Various methods of scoring and the effects of various cutting scores were analyzed. Development of an objective *Officer Evaluation Report (OER)* was begun with appraisal of current Army efficiency rating methods. The War Department *AGO Form 67, Officer Efficiency Report*, and the *AAF Form No. 123, Officer Evaluation Report* were subjected to intensive analysis including intercorrelations of sections and trait ratings and factor analysis (301, 302). The technic of collecting statements from officers and enlisted men concerning characteristics of good and poor officers and refining and scaling these statements was investigated (300). Also available were the findings on investigations of the "forced-choice" technic (295, 296). Discriminating power of every item in nine different types of rating scales was determined. The *Interview* is a standardized, objective procedure which breaks sharply with tradition. It is intended specifically to evaluate ability to deal with people. Board members observe behavior and record observations, then check descriptions, integrate these into ratings on specific areas of behavior, and finally evaluate candidate's ability to deal with people. Objectivity was achieved by defining overt behavior that could be observed and judged during the interview and developing conversational situations designed to elicit this type of behavior (299).

*Validity and Reliability of the Entire Battery.* Two purposes were intended: (a) to select officers who were outstanding in past and present performance of duty, and (b) to assure the ability of such officers to remain outstanding in the future. For achievement of the first aim, scores on the *Officer Evaluation Report (OER)* and the *Biographical Information Blank*

(BIB) for 3000 officers and on the *Interview (INT)* for 1359 officers were validated against job performance as evaluated by a large number of fellow officers. Approximately 13,000 officers were studied for development of criterion groups. Three groups, high, middle, and low, of about 1000 men each were used, consisting of men clearly and consistently placed in these categories by fellow officers in battalions or similar groups and by commanding officers. To achieve the second purpose, scores of 3000 officers on the *General Survey Test (GST)* were compared with educational level attained and scores for 367 officers on the *Officer Classification Test (OCT)* were compared with scores on the *AGCT*. A combined point-index based on the *OER*, the *BIB*, and the *INT* adequately differentiated officers on the basis of efficiency and did so in a manner far superior to the traditional Army board proceedings. Percent of most competent and least competent officers chosen by various cutting scores was determined. Mean score on the *GST* showed a high relationship to educational level achieved and showed high variability at each educational level. All instruments and the criterion were determined to have suitable reliability (298).

*New Officer Candidate Program.* Instruments devised and validated in the integration program for officers were adapted for selecting candidates for Officer Candidate Schools among enlisted applicants of the Signal Corps (303, 304) on the basis of leadership. An interview procedure, a biographical information blank, a military report, and a recommendation blank were validated against pooled buddy ratings and platoon officer ratings at various stages of training. The *AGCT* and *OCT* were found to be satisfactory predictors of academic success. This work was expanded to include the development of officer candidate selection instruments on an Army-wide basis. Forms used in the Signal Corps study were revised (312) after analysis.

*Integration of Nurses into the Regular Army.* Items for a biographical information blank (315) and an evaluation report (316) were secured from an analysis (285) of essays on good and poor nurses and from officer characteristics evaluated previously (296).

*Officer Efficiency Rating Methods.* A thoro research program on officer efficiency reporting methods grew out of the investigation of the usefulness of the semiannual officer *Efficiency Report, WD AGO Form 67*, as a selection device for the retention of wartime officers in the regular Army (298). Five methods were evaluated: the currently used *WD AGO Form 67* (301) and *AAF Form 123* (302); a forced ranking form *FR-2* (272); a report (*OER-A*) using the rating checklist technic (273); and a report (*FCL-2*) using the forced-choice technic (274, 295, 296, 297, 308). These were validated against four separate criteria: (a) Position in criterion groups of high, middle, and low officers as rated by groups of fellow officers (295, 297); (b) a criterion index score of from 0 to 60 based on these nominations (266, 298); (c) an over-all rating on a 20-point scale in comparison with Army officers in general; and (d) comparison with officers of the same grade. Results showed a clear superiority of the *FCL* over the other

four instruments (265, 266, 267, 268). In consequence, a revised form, *FCL-3*, was tried with corroborative results (269). Later studies found that validity was increased by combining the rating checklist of the *OER-A* with the *FCL-3* (309), tho the *FCL* alone is superior to the *RCL* alone; that forced ranking as used in *FR-2* increased validity slightly when incorporated with other forms, but had low validity alone; and that indorsement of ratings improved validity slightly (271), but later training had little effect (270).

## VI. Tabulating and Analysis Techniques

### Test Validity

A formula was developed for estimating the reduction in size of correlation coefficient when mean scores are inserted for "no data" cases (234), as well as formulas (207) for estimating change in  $r$  and other statistical constants due to selection on a single variable, either predictor or criterion. An empirical study of effects on obtained correlation of restriction in range led to results fairly comparable with predictions on basis of Kelley's formula (95). A method for estimating the probability of obtaining a score at or above the mean on the criterion for any given score on the predictor variable (28) was further developed (144, 145) by a method for estimating the probability that an individual with any given score on the predictor will fall at or above any given critical score on the criterion. The original method was extended to make it applicable to evaluation of significance of differences in test means for two samples (111). Two methods were presented for estimating test efficiency (166). Another approach is given in Richardson's formula (206) for interpreting a test validity coefficient in terms of increased efficiency of a selected group of personnel. A method was proposed for estimating the size of the sample required for test standardization (62).

*IBM Equipment.* Maximum utilization of IBM equipment and elimination of errors introduced by inaccurate usage were of some concern. An extra circuit added to the test scoring machine will give certain derived scores directly by shifting the zero point (43). Errors result from the use of Government Printing Office Answer Sheets when the test scoring machine is set for IBM Answer Sheets (101). Favorable conclusions were reached concerning possibility of utilizing No. 1 pencils instead of IBM pencils in marking answer sheets (135). Detailed steps necessary in checking the adjustment of the IBM Test Scoring Machine were reported (245). A tabulation was also made (45) of differences in scores between machine-scored and hand-scored answer sheets.

*Test Selection.* A procedure was developed for estimating the proportion of the variance of the total scores on a test contributed by each of the parts (130). The effect of a suppressor variable upon Wherry test selection results was also discussed (243).

*Item Analysis.* Tetrachorics were found more reliable than item-test correlations obtained with use of Richardson's Nomograph (80). Errors in the use of Richardson's Nomograph to analyze items not attempted by all subjects were pointed out (44). The effect of guessing on biserial correlations obtained between items and true scores was found to vary with item difficulty (244). Maximum  $r$  obtainable with Adkins-Toops Quintile Formula was found to vary with difficulty of item (238).

*Test Reliability.* Kuder-Richardson Formula No. 21 appears to underestimate reliability of scores based on the average of two administrations. A new formula was suggested (133). Insofar as assumptions underlying Kuder-Richardson Formula No. 21 are met, the addition of zero scores will increase the magnitude of the  $N$  obtained for all  $r$ 's less than unity (81). Kuder-Richardson Formula No. 20 appears to overestimate the reliability of a test when the distribution of item difficulty is highly skewed (200). A technic was given (200) for computing practice effect, difference in difficulty of parallel forms, and difference in level of ability for two groups taking two forms of a test.

*Computing and Facilitating Tables, Nomographs and Work Sheets or Job Descriptions.* The following devices for facilitating computations were suggested: (a) job description of Wherry-Doolittle test selection method (159); (b) job description and work sheet for computing Pearson  $r$  by "difference" (diagonal) method (187); (c) work sheet for applying Adkins-Toops simplified formulas for item-selection (238); (d) job description and work sheet for factor analysis involving thirty-five or fewer variables (124); (e) work sheet for correcting correlations for restriction on one variable (253); (f) item analysis against median split on total test score (Richardson's Nomograph) (80); (g) expectancy figures based on validity coefficients for various Army tests (232); (h) table for changing ranks in groups smaller than 100 to equivalent rank in a group of 100 (193); (i) values of  $\Sigma X$ ,  $\Sigma X^2$ ,  $\Sigma XY$ ,  $\Sigma Y$ , and  $\Sigma Y^2$  for values of  $N$  from one to twenty for each cell of a  $13 \times 13$  scatterplot (188); (j) four-place table of  $\frac{p}{z}$  for three-place values of  $p$  or  $q$  (141); (k) facilitating tables for obtaining standard *AGCT* scores from number of attempted items and number of right answers (33); (l) probable error of median for certain values of  $Q$  and  $N$  (28); (m) value of  $1-r^2$ ,  $\sqrt{1-r^2}$ , and  $\frac{r}{\sqrt{1-r^2}}$  for various values of  $r$  (2); and (n) value of  $\frac{1}{\sqrt{1-r^2}}$  and  $\frac{2}{\sqrt{1-r^2}}$  for values of  $r$  (11).

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## CHAPTER V

### Research For or By the Armed Forces

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#### Selection Research on Mental Adjustment

RESEARCH in the field of mental adjustment in the Armed Forces consisted of (a) selection studies which used tests mainly of the paper-and-pencil variety to appraise the emotional stability of servicemen and (b) studies which attempted to make the same assessment on the basis of psychiatric interviews, situation tests, and other screening procedures.

The use of the *Rorschach* in evaluating military personnel was discussed by Linn (134) in a study in which *Rorschach* records obtained from a group of enlisted men assigned to a hospital were compared with performance ratings a year later after eight months of overseas duty. Responses given by well-adjusted soldiers were markedly different in many respects from norms based on well-adjusted civilians. The hypothesis was advanced that personality constriction and regression were produced by military indoctrination.

A group of papers on the construction, standardization, application, and results of research on the *Cornell Indices* and the *Cornell Word Form*, included a report by Mittelmann and Brodman (159) suggesting that the *Cornell Service Index*, *Selectee Index*, and *Word Form* were designed to differentiate quantitatively individuals with personality and psychosomatic disorders and to facilitate qualitative diagnosis of these disorders. A report by Weider and Wechsler (261) discussed the results of the application of the *Cornell Indices* and *Word Form*, the criteria of significant answers, and validity data. Wolff (266) indicated that with their basis of clinical experience and psychological and psychiatric principles the Cornell instruments might be used at induction stations, clinics, neuropsychiatric wards, and medical and surgical wards in hospitals, or in industry, veteran placement, research, and hospitals and clinics in civilian work. Harris (78) discussed the use of the *Cornell Selectee Index* as an aid and timesaver in the psychiatric diagnosis of naval personnel.

The *Personal Inventory* was discussed by Shipley and Graham (199) who presented a report and complete bibliography of the work on that and other tests of emotional stability. Satter (188) reported a study in which the results of the *Personal Inventory* were compared with success and failure in parachute school. Satter (187) also discussed the inability of the *Personal Inventory*, the *Otis Tests of Mental Ability*, the *Two-Hand Coordination*, several other tests, and psychiatrists' evaluations to predict officers' ratings of enlisted men in the submarine service. Shipley, Gray, and Newbert (200) found that the *Personal Inventory* differentiated between discharges from the Navy and men still active in the service after

one year, between good and bad conduct cases, and between those rated and those not rated. Berry, Leavitt, and Mote (22) compared formats A and B of the *Inventory* and found them to be parallel.

Wexler (215, Chapter 9) discussed the measures of personal adjustment developed and used in the Bureau of Naval Personnel and Watson (257) the prognostic value of the psychological tests in the Navy Officer Training Program.

Selection on the basis of neuropsychiatric screening was described by Southworth (211) who presented data on rejections and factors influencing rejections at the Great Lakes Naval Training Station. Newman, Bobbitt, and Cameron (162) reported on a reliability study of an interview by two psychologists and one psychiatrist for the evaluation of officers in the Coast Guard. Biserial correlation coefficients were reported for failures to graduate from Submarine School for four tests developed thru the use of psychiatric criteria by Bartlett (16) along with evidence showing the relationship between clinical evaluations and school failure.

The psychobiological screening procedures in the War Shipping Administration were discussed by Killinger and Zubin (102) who pointed out that the screen caught 85 percent of those who would eventually have to be disenrolled. The effectiveness of battle-noise equipment as a test for emotional stability was evaluated by Hartley and Jones (79).

The selection of workers for strategic services was described by the Office of Strategic Services Assessment Staff (229). In addition to a vocabulary test, a sentence completion test, a health questionnaire, a work conditions questionnaire, and a personal history form, the process included several outdoor tests such as the *Brook Test*, the *Wall-Scaling Test*, the *Construction Test*, and several paper-and-pencil tests such as the *Map Memory Test*, the *Bennett Mechanical Comprehension Test*, and the *Manchuria Test of Propaganda Skills*. Murray and MacKinnon (160) pointed out that altho no follow-up has been completed, only one of the 300 cases selected by the OSS staff failed because of a neuropsychiatric condition.

Steinberg and Wittman (212) discussed a study of the sociological, personality, and adjustment characteristics of hospital patients who supposedly broke under camp life, of veterans in a mental hospital, and of well-adjusted soldiers. A study of the interests of Marine Corps women as measured by the *Kuder Preference Record* was reported by Hahn and Williams (77). Adams and Fowler (1) presented a report on the reliability of two forms of an activity preference blank used to select fire controlmen.

### Selection Research on Intelligence

Research in the selection of personnel on the basis of intelligence included a group of studies on the *Wechsler-Bellevue Test*. The value of five of the subtests of the Bellevue verbal scale in differentiating among normal, dull-normal, borderline, and mentally deficient groups in the examinations of naval recruits was discussed by Lewinski (113). Altus (7) con-

cluded, from a study of the validity of the *Wechsler-Bellevue*, that the validity is somewhat higher for the total scale than for *Form B* of the scale. Hunt (86) considered the use of a ten-minute individual test of intelligence, the *Wechsler-Bellevue*, reading and language handicap tests, the *Rorschach*, and various educational tests for selecting naval recruits. Correlations between the original and revised *Kent Emergency Scales*, and between the *Kent* and the *Stanford-Binet*, and the *Wechsler-Bellevue* were discussed by Lewinski (114). Greenwood, Snider, and Senti (69) described a study of the correlation between the *Wechsler Mental Ability Scale, Form B*, and the *Kent Emergency Test* administered to 200 Army personnel. A correlation of  $.74 \pm .02$  was found between the two tests and it was concluded that the *Kent* is suitable for intelligence testing in situations not permitting more extensive testing.

A study was presented by Lindsley (121) which indicated that students with an *Otis Intelligence Test* score of -1 or less would fail in the filter course at Camp Murphy, Florida. Colmen (33) described a five-minute group test which was found to be adequate and reliable for measuring intelligence without being influenced by illiteracy.

### Research in the Selection of Officers

Jensen and Rotter (91) reported that of thirteen psychological tests investigated as screening instruments, the most efficient combination for predicting academic success was the *Personnel Test* (Wonderlic modification of the *Otis Higher Examination*), the Arithmetic Computation (*Stanford Achievement Test, Advanced*), and the Combined Paragraph- and Word-Meaning sections of the *Stanford Achievement Tests*.

A program consisting of an interview in which past history rating was obtained, a standardized life-like construction test which yielded ratings on seven basic traits related to combat leadership ability, a specially devised sensori-motor test, a rapid projection test, and the group use of the *TAT*, was discussed by Murray and Stein (161).

An analysis of the records of two classes at Fort Sill Artillery School by Garrett and Ligon (67) revealed that combat efficiency was not very closely related to ratings for leadership obtained in OCS, that there was some indication that the best officers came from age range 22-28 and that above a certain desirable minimum, intelligence as measured by the *GCT* had little relevance to combat performance.

A group of studies on the selection of officers for the Navy included reports by Cornehlsen (38, 39, 215) on the growth of the selection and classification program for officers and for reserve officers for billets; by Miller and Owens (215) on the *Basic Tests for Officer Personnel*; by Frederiksen and Peterson (65) on the development and validity of the Navy's *Officers' Qualification Test*; by Gulliksen (70) outlining the specifications for an *Officers' Selection Test*; by Frederiksen (58) on the comparison of the *Officers' Qualification Test, Form 1*, and the *U. S. Navy Aptitude*

*Test, Form E-2*; by Gulliksen (72) on the preparation of *Form 1* of the *Navy Officer Qualification Test* showing that the revised test had a wide range of difficulty and a satisfactory reliability; by Frederiksen (61) on the preparation of norms for the *Officer Qualification Test, Form 1*; by Gulliksen (71) on the preparation of norms for women on the *Officer Qualification Test, Form 1*; by Peterson (172) who gave a statistical evaluation of the *Navy Officer Qualification Test, Forms 2 and 3*; and by Frederiksen (60) who discussed the preparation of a spatial relations test, consisting of multiple-choice items concerning the rotation of solid forms, for selecting radar officers. Conrad and Lannholm (215) described the prediction of success in Primary Officer Training School and Maucker (215) described such prediction in Advanced Officer Training School.

### Research in the Selection of Enlisted Personnel

The selection of enlisted men in the Navy was discussed in a group of studies. Odell (215) gave an account of the growth and development of the selection, qualification, and classification programs. Bond and Miller (215) described the development of the *Basic Test Battery*. The Staff of the Bureau of Naval Personnel (219) presented studies on item analyses, time limits, reliabilities, norm development, validity, intercorrelations, and factor analyses of the *Basic Test Battery*. The Staff of the Bureau (221) also discussed the validity of *Form 1* of the *Basic Test Battery* for selection for two types of elementary training schools. Bloom and Brundage (215) described the prediction of success in elementary enlisted schools. Curtis (215) described prediction in the advanced schools. Satter (187) found that there was no relationship between the scores on the *Otis Higher Examination*, the *Personal Inventory*, and the *Two-Hand Coordination Test* and officers' ratings of submarine crewmen on the job. Graham, Mote, and Berry (68) found that the same battery predicted "tank escape" performance failures considerably better than chance for submarine crewmen. Miller (157) reported a study on the choice of a test battery for selection of LCVP coxswains thru the use of the Wherry-Doolittle test selection method. Miller (156) also described reliability studies of six apparatus tests used with the Navy *Basic Battery* for the selection of LCVP coxswains, and in another study (154) reported that the Navy finally chose a hand dynamometer and a pegboard test from this group of mechanical tests on the basis of correlations with ratings on boat handling.

### Research in Selection of Enlisted Personnel for Particular Jobs

Studies concerning the selection of fire controlmen and radar operators included studies of vision such as the one by Adams, Fowler, and Imus (3) which discussed the relationship between visual acuity and acuity of

stereoscopic vision. Adams and others (4) found that the *Ortho Rater Tests* were sufficiently reliable as testing devices in the selection of candidates for training as fire controlmen and range finder operators. The interrelationships among seven tests of stereoscopic acuity and the relationship between two tests of visual acuity and two tests of Phorias were pointed out by Fowler, Imus, and Mote (56). The battery used in the selection of fire controlmen, range finders, and radar operators was discussed by Beier and others (21). Imus (88) presented the directions, procedures, tests, and equipment used in the selection and classification of fire controlmen. The final report on the Selection and Training of Radar Operators was made by Lindsley (117).

The Staff of the Bureau of Naval Personnel (222) described the construction of selection and achievement examinations and the conduct of technical personnel research designed to facilitate the selection and training of personnel in the maintenance and repair of electronic equipment. The predictive efficiency of the Navy Basic Test Battery at gunner's mates school was discussed by the staff of the Bureau of Naval Personnel (226).

Methods of selecting naval gun and engineering crews were discussed in a complete summary and bibliography of the Gunnery Project of the Applied Psychology Panel by Viteles, Gorsuch, and Wickens (242). Rogers, Viteles, and Voss (180) presented similar material for the Applied Psychology Panel Engineering crew project.

McQuitty (139) described the personnel selection program at an Engineering Replacement Training Center which was continuous, being co-ordinated with the training program, and was based upon the *AGCT* score, formal education, and first and second best civilian occupations. Selection for specialists' courses was on the basis of interest, success in a specialty, related hobbies, educational background, and aptitudes.

The work on the selection and training of night lookouts, including a discussion of validation of old night-vision tests, of the measurement of the performance of night lookouts at sea, and of an analysis of the night lookout's job, was summarized by Wedell (259). In a study of hearing in searchlight and other personnel requiring exceptionally good hearing, Clarke (31) reported that audiometers were unsuited for mass testing of acuity of hearing and suggested that gramophone records with words of varying intensities be employed. The study reported that only 40 percent of the 100 soldiers trained as listeners or spotters appeared to have, for both ears, hearing superior to three decibels loss. The best combination of tests for selecting Army weather observer students was reported by Cleveland, Faubion, and Harrell (32) to be a mental alertness test, a physics achievement test, and a meteorological achievement test.

Kurtz, Seashore, and Willits (107, 105) presented a discussion of the Code Receiving Tests developed by the Applied Psychology Panel.

Reid (178) reported that in aptitude tests for drivers in the Third Armored Division, the greatest number of failures occurred for glare blindness, defective acuity, and depth perception. A yarn test for color vision,

a field of vision test, and tests of depth perception, glare, balance, stability, reaction time, and visual acuity were given to 10,000 prospective heavy-truck drivers in this study. The selection and training of cargo handling teams for combat-laden vessels was discussed by Ruch (185).

Selection tests and causes for rejection were described by Thomas (224) in a report on the selection of parachutists.

A report on the construction of various performance tests, group and individual, and of checklists for objective observation in the Teacher Training Department of the Armored Force School, Fort Knox, was presented by Siro (202).

### Research on Classification and Aptitude Tests

Research in classification in the services included studies such as those McCain and Schneidler (135) discussed concerning the classification and selection of enlisted personnel. Eurich and McCain (50) also described the initial classification in which each recruit was given the general classification, reading, arithmetic reasoning, mechanical aptitude, clerical and mechanical knowledge tests, an interview, and then a recommendation for two possible jobs. The specifications for the construction of a general classification test, a reading test and a test of arithmetical reasoning were outlined by Frederiksen (62). The selection of items and a comparison of the selected items with those previously used for the *General Classification Test, Form 2*, and for the tests of reading and arithmetic was described by Satter (189). Wrenn (270) included in his description of Navy personnel procedures the nature of the classification interview and the training of interviewers. The derivation of national norms for the Fleet Edition of the *General Classification Test* was described by Peterson (171) who concluded from the data collected that the *GCT* (x-l-s) served satisfactorily as a self-administering test and constituted a parallel form of the *GCT, Form 1*. He (170) also reported on a factor analysis of the new *Navy Basic Classification Test Battery*. A statistical evaluation of the *Basic Classification Test Battery, Form 1*, led Conrad (35) to the conclusion that the battery competently fulfills the essential requirements.

Procedures and tests used to select men for assignment to fill the balance crews for newly commissioned destroyers on the Pacific Coast were discussed by Levin (111). The work of the Classification Section of the Armored Force Replacement Training Center described by Wittman (264) included material on the psychological, clerical, and mechanical-aptitude testing; on occupational interviews, testing and classification; on assignment to different military duties; on the selection of officer training candidates; on the liaison relationships with regular training companies; on the record keeping and planning of activity flow; and on research and selection of men for the Special Training Unit which handles and studies physical, mental, and psychological problems. Malone (142) described the Army Classification system, the use of the *AGCT*, the *Mechanical Aptitude Test*,

and the *Radio Operators Aptitude Test*. An activity preference test furnishing a number of scores corresponding to clusters of functionally related activities was reported by Kelley (100) who outlined the steps leading to its development. The selection of personnel with superior vision for the crew of the *USS New Jersey* was described by Verplanck (231) in a study using an NDRC Adoptometer Model II.

Research on aptitude tests for the Navy was reported by Frederiksen (63) who described a study made on an experimental battery of aptitude tests as predictors of service-school grades for inclusion in the *Basic Classification Test Battery*; by Conrad (36) who presented the research and developmental history of the Navy's aptitude testing program; by Conrad (34) who also discussed the basic statistical facts concerning individual items of the *Navy Aptitude Tests* and interpreted these facts with reference to various problems; by Stuit and Feder (215) who described the development of special aptitude tests by the Bureau of Naval Personnel; by Gulliksen, Conrad, and Frederiksen (75) who confirmed an earlier conclusion, by studying the averages, standard deviations, and intercorrelations of the Navy aptitude tests, that variations in procedure from one station to another constitute a serious problem; by Gulliksen (73) who compared the selection of test items for a mechanical comprehension test by an item analysis based on an external criterion and by the technic of item-total correlation and also (74) presented minor modifications which could be made in a short time to the *Navy Mechanical Aptitude Test, Form T*, and made suggestions for a more thorough revision of the test.

Validation research was presented by Frederiksen (64, 63) in a discussion of the validities of aptitude tests at various schools; by Crawford and Burnham (45) in a report on the results of the educational aptitude testing of V-12 students in which it was found that aptitude tests proved to be effective predictors of academic work measured by objective achievement tests; and by Anderson and others (10) in a paper on the Oscilloscope Operator tests. Prediction of ability was discussed by Kurtz (104) in relation to code learning. Prediction of success in Electricians' Mates School was presented by Conrad and Satter (37) in a discussion of the use of test scores and quality classification ratings. A report was given by Smith and Voss (206) on a study of the effectiveness of the classification procedures for officers of the Amphibious Training Command. Smith and others (207) also reported on the effectiveness of classification data in predicting billet performance in training in the Amphibious Force. Prediction of success in service school from the order of assignment was discussed by Satter and Conrad (190). A study presented by Wedell (260) reported on the prediction of the performance of night lookouts.

Procedures used in a job analysis of the tasks performed at gun stations were enumerated by Viteles and Smith (243). The final report and summary of work in job analysis qualification and placement of personnel in the Amphibious Force was presented by Smith (205).

A selectometer for weighting the qualities on which interviewers rate

men was discussed by Keislar (93) and by Campbell (30) who made a final report on research and development of classification aids. Another classification aid, the point-score method for evaluating Naval personnel was presented by Levin (112). Viteles (233) presented an interviewer's recommendation chart which shows in visual form the billets aboard ship for which an individual with given qualifications is most adapted. The personal preference technic, which employs the opinions of co-workers or students who have had adequate time to observe their fellows, was discussed by Wiggin and Bartlett (263) as a possible supplement to instructor's grades.

### Research on Training

In an article on military training and learning theory, Wolfe (267) indicated that help was given to military specialists in World War II by psychologists who applied such principles of learning as distribution of practice, active participation, variation of material, accurate records of progress, knowledge of results, and systematic lesson plans. Applications of these theories appeared in some of the work discussed below.

Gunnery-training research included such studies as the ones discussed by Viteles *et al* (235, 245, 246, 249, 251, 252, 253), outlining training aids, lesson plans, and courses of instruction for a four-day course in 20 mm and 40 mm gunnery; by Viteles (234) who investigated the scoring characteristics of the Machine Gun Trainer, Mark 1; by Smith *et al* (208) presenting a memorandum on gunnery teaching; by Covner and Viteles (40) presenting instruction in engineering, damage control, and gunnery at the CVE Precommissioning School; and by Viteles, Gorsuch, and Wickens (241) describing the standardized four-day courses using unit lesson plans for a gunnery-training program, and the study of synthetic training devices. Range-estimation studies included Wickens, Gorsuch, and Viteles' (262) account of lesson plans for instruction on the mirror Range Estimation Trainer Device 5C-4; Voss and Wickens' (255) comparison of free and stadiametric estimation of opening range; Horowitz and Kappauf's (84) description of the accuracy of unaided visual range estimation for aerial targets at ranges between 1500 and 8000 yards; Viteles *et al*'s (248) analysis of the results obtained in training men in range estimation on the firing line; and by Rogers' (181) evaluation of methods of training in estimating a fixed opening range. Hoffman and Mead (82) discussed the performance of Anti-Aircraft Artillery personnel on a complex task of four-hours duration. Research in the training of engineers was discussed by Rogers, Viteles, and Voss (179, 180); and by Viteles, Gorsuch, and Watters (240) who discussed the improvement of a training program for newly organized crews for destroyers and for auxiliary ships. Masoner and Watters (149) presented an instructor's manual which served as a guide in the administration of special engineering courses. A manual for training balance crew engineers for attack

transport vessels was described by Covner, Gorsuch, and Viteles (41). Viteles and Gorsuch (236) prepared a memorandum on effective teaching methods for engineering instructors. A group of studies concerned with progressive engineering were reported by Viteles and Gorsuch (237, 238) who presented lesson plan outlines for Stages I and II of the instruction; by Organist *et al* (167), who prepared an instructor's manual for Stage II and who presented outlines for instructions in Stage III (165); and by Organist and Willis (166) describing the organization and instruction for Stage III. Covner *et al* (44) prepared an instructor's manual for presenting information on the distilling plant to engineering personnel.

The training of fire controlmen and range finder operators was presented by Beier *et al* (20) in the form of a series of lesson plans. The influence of visual tasks in the training course of fire controlmen upon their visual proficiency was discussed by Adams, Beier, and Imus (2). Covner, Gorsuch, and Viteles (42) presented a manual for instructors with a detailed step-by-step procedure for operation of fireroom equipment on destroyer escort vessels.

The training of radar operators was reported on by Lindsley *et al* (132), who discussed the use of the Philco trainer for A-scan oscilloscope operators; and by Lindsley *et al*, in a series of articles (120, 128, 133), describing and presenting recommendations and generalizations for the use of the PPI flash-reading and tracking trainers in training Navy search-radar operators. Lindsley (119) also gave an account of the results of a study determining the effectiveness of the course of training SCR-270-71 radar operators. The effectiveness of the Foxboro Trainer in training oscilloscope operators to track by means of pip-matching was evaluated by Lindsley and others (129), who also made recommendations for its use (127). A study of the SCR-584 basic trainer as a device for teaching range tracking was presented by Lindsley *et al* (130) and by Anderson *et al* (9). The Lufts Tracking Trainer was described by Hudson and Searle (85). The results of developmental work done on the design and construction of a director tracking trainer and experiments to determine the effects of various fatiguing circumstances on performance were summarized by Mead (151). Kappauf (92) reported on phototube scoring devices for tracking trainers. An experimental investigation involving a comparison between tracking to a fixed hairline and tracking to a rotating hairline was presented by Lindsley *et al* (124). Experiments in training radar operators in visual code reception were discussed by Anderson *et al* (8) and by Lindsley *et al* (125). The use of radar scope movies for briefing and reconnaissance purposes was evaluated by Lindsley (122). A study of performance was reported by Lindsley and others (131) concerning the reactions of radar operators under speed stress. He also described the factors determining the accuracy of reading oscilloscope code in a study (126) designed to find the speed, width, amplitude, dot-to-dash ratio, and letter-code cycles at which code can most accurately be read.

An extensive group of studies concerning the training of telephone talkers

was discussed by Black and Mason (24); by Snidecor, Mallory, and Hearsey (210) in relation to the use of mass drill, continuous prompting, instruction by skilled men, dramatic recording, criticism, and discussion as methods of training telephone talkers for increased intelligibility; by Hibbitt and Mallory (81) in relation to an experimental investigation of a course for telephone talkers; by Curtis (46) in relation to increasing the intelligibility of voice communication by training in voice technic and (47) in relation to the use of noise in a training program; by Abrams and others discussing the factors determining the intelligibility of speech in noise; and by Mason (146) concerning the effects of training on articulation. Mason and others (147) reported on the indoctrination of air-crewmens in voice communication at altitude and (148) on the training studies in voice communication. Studies of the effect of pitch on the intelligibility of voice communication were discussed by Mason (145). The relationship between loudness and intelligibility of airplane inter-phone communication was pointed out by both Curtis (48) and Talley *et al* (218). Reports on the analyses of mistakes made in word intelligibility tests over the T-17 microphone (144) and on the phonetic characteristics of words as related to their intelligibility in aircraft type noise (143) were made by Mason. Intelligibility in relation to various methods of holding the T-17 microphone for communication in noise was discussed in a report of the Psychological Corporation (177). Talley, Curtis, and Haagen (217) reported on a related study on microphone position in voice communication. Snidecor (209) dealt with a preliminary study of the ability of rated men to judge speaking performance. Anonymous articles gave accounts of a study in training Classification Petty Officers to select telephone talkers (14) and of a speech interview for the selection of telephone talkers (13). The final report in summary of the work on the selection and training of telephone talkers was made by Mallory and Temple (141). An account of the technics and procedures used by the Voice Communication Laboratory was presented by Haagen (76). The final summary of work on voice communication was given by Black (23).

Reports on training studies in radio code work include a summary of research in Radio Code Project N-107 by Kurtz and Seashore (106) and in Project SC-88 by Keller (95); a comparison of training methods at two levels of code learning by Keller, Estes, and Murphy (98); reports by Keller and Estes (96, 97) on the effectiveness of different types of practice in code learning and by Keller (94) on the code voice method of teaching; a comparative study of three methods of teaching code in the early weeks of the course by Seashore and others (195); and a discussion of the standardization of code speed by Kurtz, Seashore, Stuntz, and Willits (108). The development of a graduation and rating test for Class A radio schools was discussed by the staff of the Psychological Corporation (176). A group of four studies concerning methods to be used in code classes included Seashore and others' (197) discussion of variation of activities to prevent monotony in code classics; their (196) report on

the effect of introducing sending code early in the course upon learning to receive; Seashore and Stuntz' (194) manual of activities for reducing monotony in code schools; and their (193) experimental study of the training of radio operators to copy code thru interference. Seashore and Kurtz (192) presented an analysis of the errors made in copying code.

A miscellaneous group of training studies included a report by Ruch and others (186) outlining training procedures and lectures on winch operations and presenting a rating form for grading trainees on electric winch operation; a critical evaluation by Shuttleworth (201) of the Army Specialized Training Program with reference to selection standards and the method of "block training"; a discussion by Layman and Boguslavsky (110) of the relationship between ability and achievement in the Army Specialized Training Program which pointed out that "neither secondary schools nor colleges were sufficiently challenging to induce maximum relationship between ability and academic achievement in many individual instances"; a presentation by Carstater (215) of the Bureau of Naval Personnel program for officer training and one by Batchelder (215) for enlisted personnel. Feder (53) reported standardization of instruction in several Navy schools concerned with elementary electronics training thru the construction of an achievement test and the standardizing of procedures on the basis of test results.

### Training Devices

Discussions of studies concerning training devices included Exton's (52), Noel's (163), and Stott's (213) accounts of the use of audio-visual aids in expediting the Navy training program. Wattles (258) presented the results of the teaching of gunnery with aids such as flash cards, films, rating sheets, lesson plans, and observation record forms for evaluating the instructor. Ullman (227) described the procedures of several night-vision training devices. Lanier (109) explained a night lookout trainer for use aboard ship. Dresser (49) examined the use of slide films in the Navy training program. Witty and Goldberg (265) discussed the use of flash cards, training films, film strips, picture portfolios, bulletin boards, posters, cartoons, maps, diagrams, charts, and other visual aids in special training units in the Army. An anonymous article (90) described the shortcuts in learning skills, ways to speed training, study books, manuals and lessons, and other aids to military training. Thomas (225) reported on the use of animated cartoons in training and indoctrination in the Army. A discussion of ship models in classroom instruction and other training aids was presented by Viteles and Gorsuch (239).

Viteles and others (250) presented a discussion of the psychological principles involved in the design and operation of synthetic trainers with particular reference to anti-aircraft gunnery. Viteles and others (247) also described an investigation of the Range Estimation Trainer Device 5C-4 as a method of teaching range estimation. The use, characteristics,

advantages, and disadvantages of all the synthetic trainers used by the Applied Psychology Panel projects were compared with training on real equipment by Wolfe (268).

### Morale Research

Discussions concerned with the factors affecting morale included a report by Madigan (140) which emphasized the difficulties in army adjustment and the ways in which morale problems might be countered; one by Prattis (173) concerning the morale of the Negro in the Armed Services under the treatment received; and one by Evans (51) and one by O'Gara (164) pointing out some factors affecting military morale. Blain (25) discussed the war neuroses of merchant seamen and the personal and morale factors involved in their etiology and prevention. Homans (83) reported on the problems in morale and leadership on small warships. Woods (269) discussed the morale factors of naval noncombatants; Baganz, Mearin, and Woods (15) presented an account of the mental mechanisms and morale factors of Naval recruits in training. An anonymous writer (89) summarized the points mentioned by soldiers as the features of army life most closely related to morale. A consideration of the development of rumors in the service and the ways of checking them was presented by Kelly and Rossman (101).

Discussions of the factors which build morale included a presentation by Bassan (17) of factors found valuable in maintaining morale on a small combat ship; an account by Smith (204) of the personnel policy of the Navy and its relation to morale; a report concerning the problems of procurement, training, and morale among members of the Women's Reserve of the U. S. Coast Guard by Stratton and Springer (214); a description by Rose (182) of the bases and weaknesses of American military morale in World War II; considerations by Schroeder (191) and by Kreinheder (103) of the orientation program in the Army and the qualities of good orientation officers; an anonymous article (153) concerning planned orientation for combat, orientation objectives, and the execution of the orientation course; a presentation by Brosin (28) of a program for utilizing the marginally unfit in the Armed forces and an analysis of the basic principles involved in morale improvement; a description of an analysis made of the morale of American occupation troops before and after the end of World War II and means of improving military morale by Warner (256); and a report by Rottersman (183), based on the analysis of 20,000 selectee questionnaires regarding complaints, on morale as a factor in complaint reduction.

Civilian research in morale included Allport and Schmeidler's history (6) of a clearing house to aid psychologists in problems of morale. Shils (198) discussed the effect of governmental investigation on attitudes and morale. Appel and Hilger (12) presented a morale and preventive-psychiatry program in the Army. Osborn (168) summarized the services of

the Morale Branch of the War Department as they affected the recreation, welfare, and morale of the American soldier.

### Leadership Studies

A suggestion was made by Miller (158) that leadership could be taught by actual training under officers who are themselves good leaders and by experiencing leadership and its problems. A discussion by Metsker (152) included material on the mental characteristics of military leadership from the standpoints of selecting and training leaders. Mayberry (150) described an interview rating scale and technics employed in evaluating leadership qualities of officer candidates. McNassor (138) and Bavelas (18) discussed the training of leaders, and MacKechnie (136) reported on the development of leadership in small unit commanders. An outline syllabus, used as an aid in the Academy's first course on the psychology of military leadership, was presented by the U. S. Military Academy at West Point (228). Intangible factors in combat, including teamwork and leadership were considered by McLain (137). Garrett and Ligon (66) in a report on combat leadership concluded that unless leadership is defined in some way which permits direct measurement of specific qualities, research on predictive items is likely to be useless. Ligon (116) discussed the problems of choosing efficient officer candidates, reports from combat area, and interviews with ex-combat officers concerning the characteristics of good combat leadership. A study of traits most frequently mentioned for a good officer and for distinguishing a good officer from a good enlisted man was reported by Heath and Gregory (80). Ageton (5) presented a discussion and bibliography on military leadership and training methods. The development of a manual for instructors of leadership courses in Officers' Training School was presented by the Staff of the Bureau of Naval Personnel (29). The OSS Staff (229) gave an account of the measurement of leadership in life situation tests such as the *Mined Road*, *Getting Past the Sentry*, *The Blown Bridge*, and *Killing the Mayor*, where candidates were assigned leadership and expected to lead a group of men.

### Proficiency and Achievement

Problems in the measurement of achievement in Naval Training Programs, the types of tests developed and the outcomes of the Achievement Examination Program were described by the Staff of the Bureau of Naval Personnel (220). A group of reports on achievement included Ryan's (215) and Feder's (54) discussions of the services provided to Navy Training thru achievement examinations; Porter and Harsh's (215) presentation of achievement examinations for elementary enlisted schools; Feder and Lawrence's (215) account of the measurement of achievement in the Radio Technician Training Program; and Cruikshank and Darling's (215) description of the *Advancement in Rating Examination* developed

by the Bureau of Naval Personnel. Anderson and others (11) discussed vision as related to proficiency in oscilloscope operation. Lindsley (123) wrote on the same topic and gave recommendations concerning minimum visual standards for radar operators. Ruch (184) evaluated a subjective and an objective technic for rating winch operating ability. Prentice (174) reported a study of the performance of night lookouts aboard ship. Keller and Jerome (99) outlined a system for describing progress in receiving International Morse Code. The construction and validation of a work readiness test for distilling plant operators which served as an objective technic for evaluation proficiency was described by Covner, Voss, and Wesley (43) and by Voss and Wesley (254).

### Criterion Measures

Discussions of research on criterion measures included Bechtoldt's (215) and Patterson's (169) articles on the problems of the criterion in prediction; Sisson's (203) description of the criterion in Army personnel research and the results of an exploration of the "nomination" technic as a possible criterion of soldiers' performance, which showed a correlation of the order of .50 between scores on a selected test battery for enlisted men and high and low "nominations" by fellows for competence; and Vaughn's (230) discussion of this same technic which gave evidence of value as a criterion in exploratory studies with Navy pilots.

Methods of obtaining criteria of shipboard competence appeared in a discussion by Bechtoldt, Maucker, and Stuit (19). Franzen presented (57) a method for selecting the best combination of dichotomous arrangements to distinguish a categorical criterion. The effect on prediction of success of an increasingly well-defined criterion was described in an article by Stuit and Wilson (216). Miller (155) presented a discussion of the selection and reliability of a criterion of proficiency in operating the LCVP.

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## CHAPTER VI

### Wartime Research in Psycho-Acoustics

MARK R. ROSENZWEIG and GERALDINE STONE

THE PRESSING demand for effective voice communication during the war stimulated widespread research in psycho-acoustics—the application of psychological methods to problems of acoustics, speech, and hearing. Existing communication equipment and technics had to be tested; new equipment and technics had to be designed. Typical wartime noises had to be measured and studied, their effects evaluated, and some of them combatted. Human factors in communication had to be determined, utilized, and allowed for. Some of the studies directed toward these problems are mentioned in this chapter.

Summaries of the extensive research on psycho-acoustics of the Applied Psychology Panel are contained in the book, *Human Factors in Military Efficiency—Training and Equipment*, by Wolfe and others (135) and in two reports by Black (18), and by Mallory and Temple (87). The work of the Psycho-Acoustic and Electro-Acoustic Laboratories, Harvard University has been summarized by Miller, Wiener, and Stevens (97). This book includes references to relevant work performed at other laboratories and considerable background information.

#### Voice Communication

Basic to the investigation of speech material, communication personnel, and communication equipment was the method of "articulation tests" (30, 31, 59, 60, 61, 111, 126). This was a method of testing communication systems by determining how well they serve to transmit speech. Carefully chosen speech items were employed; the proportion of items correctly received provided an indication of the relative effectiveness of the system. For any devices under consideration, as, for example, microphones, articulation tests could be used to indicate the relative effectiveness of different possibilities: carbon microphones, dynamic microphones, and magnetic microphones. Alternatives to the formal articulation test were abbreviated testing methods (31), subjective appraisal of intelligibility (6, 31), and threshold methods for evaluating intelligibility (31).

#### Speech Material

The type of speech material used was found to be an important factor in intelligibility. Analyses were made of the phonetic characteristics of words as related to their intelligibility (1, 3, 6, 18, 89, 90). Recordings of messages made in combat situations were analyzed to provide information about common errors and failures of communication (7, 18). Intelligi-

bility involves not only the physical characteristics of speech material (acoustics spectra) but also such characteristics as the average number of sounds per word, the relation of a word to other words in the language, and apperceptive variables (97). On the basis of such considerations, there were tested and constructed highly intelligible vocabularies, phonetic alphabets, standard forms of command, and lists of call signals and telephone directory names. Various procedures for the pronunciation of numerals were also tested (1, 2, 3, 5).

### Distortion

Distortion and interference are also factors in intelligibility. Experiments on amplitude distortion were performed with nonlinear circuits which either clipped the peaks or the center of the signal, or rectified the signal. The effects of each type of distortion on intelligibility were determined by articulation tests, and various measures of distortion were compared for their relation to the impairment of intelligibility (78). The effects of adding noise, both before and after distortion, were studied. Peak clipping (58, 73, 75, 76, 78, 79, 81, 85) was found to improve the intelligibility of a signal if measurement was in terms of peak voltages. Such peak clipping may be used to advantage in hearing aids to protect the ear at high intensity levels, in AM radio transmission to allow continuous 100 percent modulation, and in radio telephony to improve intelligibility when static is present. Center clipping and rectification, on the other hand, were found to be detrimental to intelligibility.

The effects of frequency distortion on intelligibility were investigated with the use of low-frequency cut-off (43, 125), gradual "tilted" cut-offs (58), and band-pass filters (39, 40). Various levels and spectra of masking noise were used. Results showed that an adequate speech-to-noise ratio should be provided over as wide a frequency range as possible. For ideal speech transmission, the frequency range should extend from about 200 to 7000 cps, and the signal-to-noise ratio at each frequency should be 25 db or more. Combined frequency and amplitude distortion was studied with speech material that was both "tilted" (i.e., put thru a system with an oblique response characteristic having a regular gain per octave) and peak clipped (58).

The quality of speech was found to change at high altitudes (71, 80, 113). Attempts to improve the intelligibility of speech at high altitude thru deliberate frequency distortion gave little success (96). Modifications of equipment resulted in improved performance (83).

### Interference

Interference was a major problem of military communication, and an extensive range of signals and noises was investigated to determine what factors contribute to their effectiveness for masking (39, 48, 62, 93, 95,

112, 123, 125, 128). The important dimensions of interference are its intensity, frequency, spectrum, temporal continuity, and annoyance value. Noise was found to mask best when it is uninterrupted and when it has a broad spectrum with a signal-to-noise ratio that is constant at all frequencies. Greater annoyance is caused by interrupted and high-frequency interference. Pure tones do not mask speech effectively, but continuous tones of low fundamental and rich in harmonics mask almost as well as noise, and they are more annoying. Speech can be used to mask other speech, but its spectrum and not its meaning is the chief factor in masking.

The effect of interference was investigated also in the case of radio range signals (50), and radar signals (53).

### Selecting and Training Personnel

Since an effective communication system requires good talkers and listeners, research was conducted in selection and training of personnel. Studies were made on the rating of talkers (6, 15, 100, 109, 110, 120, 121). Voice factors found to be closely related to intelligibility were loudness (21, 22), and intensity control (100), and precise articulation (92). Factors showing a slight relation to intelligibility were pitch (91), voice spectrum (6), rate of speaking (18), telephone experience, education, listening ability, and memory span (100). General American dialect was found to be slightly more intelligible than Southern or Eastern (100).

It was easier to test listeners than talkers, because standardized phonographic tests could be given to many listeners at once (24, 69, 107). Articulation tests given under relatively quiet conditions were found not to show who will listen well in noise (110). Noise generators were therefore designed for testing and training programs (11, 12, 48, 101, 127). Experiments suggested the existence of an ability to listen in noise which is independent of distortion due to particular equipment of the spectrum of the interfering noise, and of the type and mode of presentation of the speech material (69). Slight relation was found between listening ability and the following measures (69) : code ability, intelligence as measured by the *GCT*, auditory memory span (4), and speaking ability. Listening ability was found to be somewhat related to region of residence (18). Experiments were also made to determine the nature and extent of individual differences in the detection of small changes in noise; tests were constructed for discrimination of pitch and loudness of noises (68). These have not yet been used in studying listening ability.

Rapid and extensive improvement of performance was obtained with training of both talkers and listeners (18, 110). Several training programs were devised and tested (5, 16, 23, 24, 64, 88, 92, 99, 122); manuals and syllabi were prepared (8, 9, 10, 14, 99); special training equipment was designed and used (11, 98). The improvement found was attributed to several factors; training in voice technic (23), training in the use of communication equipment (6, 13, 32, 47, 104, 110, 129), and training in the

identification of words that are partially masked by noise or distorted by characteristics of the equipment used (24, 110).

### Communication Equipment

Along with speech material and communication personnel, communication equipment was studied in the over-all program of bettering military communication. The testing methods used by the Harvard Psycho-Acoustic and Electro-Acoustic Laboratories and the results they obtained are reviewed in a technical summary report (97).

Microphones were tested with the human voice and with artificial "voices" (17). The properties of earphones were tested by utilizing the responses of listeners; by measuring sound pressures at the ear canal with a probe tube (102); and by the use of artificial "ears" (17, 132). The pressure distribution in the auditory canal was also obtained in a progressive sound field by use of the probe-tube technic (133). Earphone cushions, earphone sockets and headsets (36, 37, 41, 57, 116), and masks (74) were tested for their effects on communication. Measurement was made of physiological noise generated under earphone cushions (94). The characteristics of microphones (56) and noise shields (35, 131), amplifiers (80), radio link (21), and receivers (20, 33, 86) were investigated. Studies were made of radio equipment, interphone equipment (43, 46, 71, 80, 83), sound-powered equipment (38, 54, 134), and radio-range equipment (55).

### Effects of Noise on Psychomotor Efficiency

One of the first military projects of the Psycho-Acoustic Laboratory was to study the effects on psychomotor efficiency of intense noise and vibration (123, 128). A battery of psychological, psychomotor, and physiological tests was developed and used to evaluate the effects of noise on a wide variety of tasks. In some of the experiments subjects were exposed to 115 db of airplane noise for seven-hour work days over a one-month period. The subjects reported the noise to be disagreeable and tiring, but their performance was largely unimpaired by it. They had temporary hearing losses following exposure to noise—losses whose extent and duration depended upon the over-all intensity of the noise, its spectrum, and length of exposure. Other reports give fuller information in intense stimulation as the cause of temporary deafness, injury of the inner ear, and other physiological effects (25, 26). In one of the psychomotor tests the subjects' coordinated serial reaction time showed an increase of 5 percent in the noise. This was actually the greatest effect of acoustic stress shown by any of the psychomotor tests, and the validity of this result is open to question. No other test showed significant decrements of performance due to noise. Indeterminate effects of noise were found in the following tests: muscular tension, metabolism, breathing, speed of accommodation, saccadic move-

ments, body sway, hand steadiness, reversible perspective, and dark adaptation. No effects of noise were found in these tests: coordinated serial pursuit, serial disjunctive reaction time, fast-speed pursuit rotor, card sorting, coding test, and judgment of distance. Vibration caused a considerable reduction in visual acuity in every subject. An extensive investigation was made of sound as a military weapon (19). Direct use of sound as a weapon was found to be impractical because it required too great an expenditure of energy.

### Noise Measurement

Investigation of the effects of noise on communication and psychomotor efficiency required measurement of noise intensities and spectra. The problems and methods which this entailed have been reviewed by Miller, Wiener, and Stevens (97).

### Combatting Noise

Noise reduction, sound insulation, and aural protective devices were used to lessen impairment of communications and to reduce annoyance (97). Airplane noise was attenuated by sound-proofing materials (29). Sound insulation was accomplished by proper design of earphone cushions, sockets, and headsets (34, 42, 45, 49, 57, 114, 116, 118) and by development of special insert tips for use with miniature earphones (117). Protection against noise and gun blasts was afforded by special earplugs (70, 77, 115). Reception of speech slightly above normal levels was not impaired by the use of these earplugs; in noise, audibility of speech was, in some instances, improved by their use (72).

### Hearing Loss and Hearing Aids

Several tests were developed for the direct measurement of hearing loss for speech (67, 105, 106, 108). These tests employ recordings of selected words and sentences, the loss being measured from standards set by normal subjects. The use of such test material transmitted thru filters may allow differential diagnosis of uniform losses and high-frequency hearing losses for speech (65). The tolerance of normal and hard-of-hearing subjects for intense sounds, both pure tones and speech, was determined. Thresholds of discomfort, of tickle, and of pain were measured (119).

Commercial hearing aids were evaluated on the basis of electro-acoustic and psycho-acoustic measurements (97, 102, 103). Studies of design objectives for hearing aids (27, 28, 66) indicated the desirability of these properties: uniform frequency response between 300 and 4000 cps, limitation of maximum acoustic output, an effective gain control with a range of at least 40 db, and no acoustic feedback or electrical feedback ("squeal").

## Auditory Signals for Instrument Flying

The possibility of putting some airplane instrument indications in auditory form was investigated (51, 52). Auditory signals were devised which "sounded like the behavior of the airplane," and which did not interfere with reception of radio-range signals or voice communication. An "automatic annunciator" was developed to translate instrument indications automatically into spoken messages and to announce them to the pilot. The annunciator had a readily identifiable speech quality, and there was little difficulty in distinguishing between it and outside speech sources.

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